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FILE NO. P3-10

PRELIMINARY PROCESS DESIGN FOR TREATMENT AND NEUTRALIZATION OF EXISTING SOLID AND LIQUID WASTES AT THE APEX MINE

Prepared for:

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Project No. 22201

2.0 FACILITIES AND PROCESS DESCRIPTION

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The mill and existing waste disposal ponds are located 12 miles west of St. George, Utah, and 0.5 miles south of State Highway 91. The site shown on Figure 2-1 lies in a broad valley at an elevation of about 3,700 feet.

The processing plant and disposal facilities are located on the eastern slope of the Beaver Dam Mountains at the head of a small catchment. About 100 acres will be affected by the processing facility, including 15 acres for the mill and 85 acres for the tailings disposal ponds and related structures.

The Apex Mine is designed as a 100 tpd operation and will process about 312,000 tons during the 13 year mine life. The processing plant shown on Figure 2-2 will operate 24 hours per day and five days per week. The mining and processing operations are scheduled to begin in the first quarter of 1990.

In the new process, the ore will be delivered to the plant by truck and stored in a run-of-mine stockpile about 250 x 250 feet in size. The ore will be delivered in a moistened form to control fugitive dust emissions. Ore from the stock pile will be transferred by front-end loader into a hopper and stored in a fine ore bin. The ore will then be fed into a ball mill and wet-ground to 35 mesh.

The ground ore will be leached in three countercurrent stages at 80°C with sulfuric acid, sodium chloride, and sulfur dioxide. The pregnant leach solution will contain about 20 g/L chloride at a pH <1.0. The leached residue will be washed in three countercurrent decantation stages with a barren recycle solution, obtained from the zinc thickener overflow.

Copper will be precipitated from the leach solution by adding iron powder in three stages. The majority of the soluble lead and arsenic are precipitated with the copper. The chloride levels in the concentrated discharge are further increased to three molar by the addition of sodium chloride. The gallium and zinc are extracted by a tertiary amine and solvent, and stripped by dilute sulfurous acid. The sulfurous acid is a by-product of the sulfur dioxide generation process. The product strip solution will contain gallium, zinc, and a small quantity of iron. The three metals are then separated by a differential precipitation process. Gallium is precipitated first by adjustment of the solution pH to 5.0. The iron is then precipitated through oxidation at a pH of 4.0. Finally, the zinc is precipitated by raising the pH to 7.5 using ammonia and sodium carbonate or soda ash.

The germanium in the solvent extraction raffinate is precipitated by the addition of hydrogen sulfide to form a low grade precipitate. The precipitate is dissolved in an oxidizing hydrochloric acid leach, using sodium chlorate as the oxidant. The germanium is solubilized as a chloride, which is distilled from the pulp by heating to 104°C. The germanium in the distillate is hydrolyzed by neutralization with ammonia, forming germanium hydroxide and oxychloride. A simplified flowsheet of the process is presented on Figure 2-3.

The process will generate 806 tons/year of cement copper, 980 tons/year of zinc hydroxide, 61 tons/year of a 32% germanium concentrate, and 44 tons/year of a 25% gallium concentrate. The cement copper and zinc hydroxide will be spread onto concrete pads and air dried to 10% moisture.

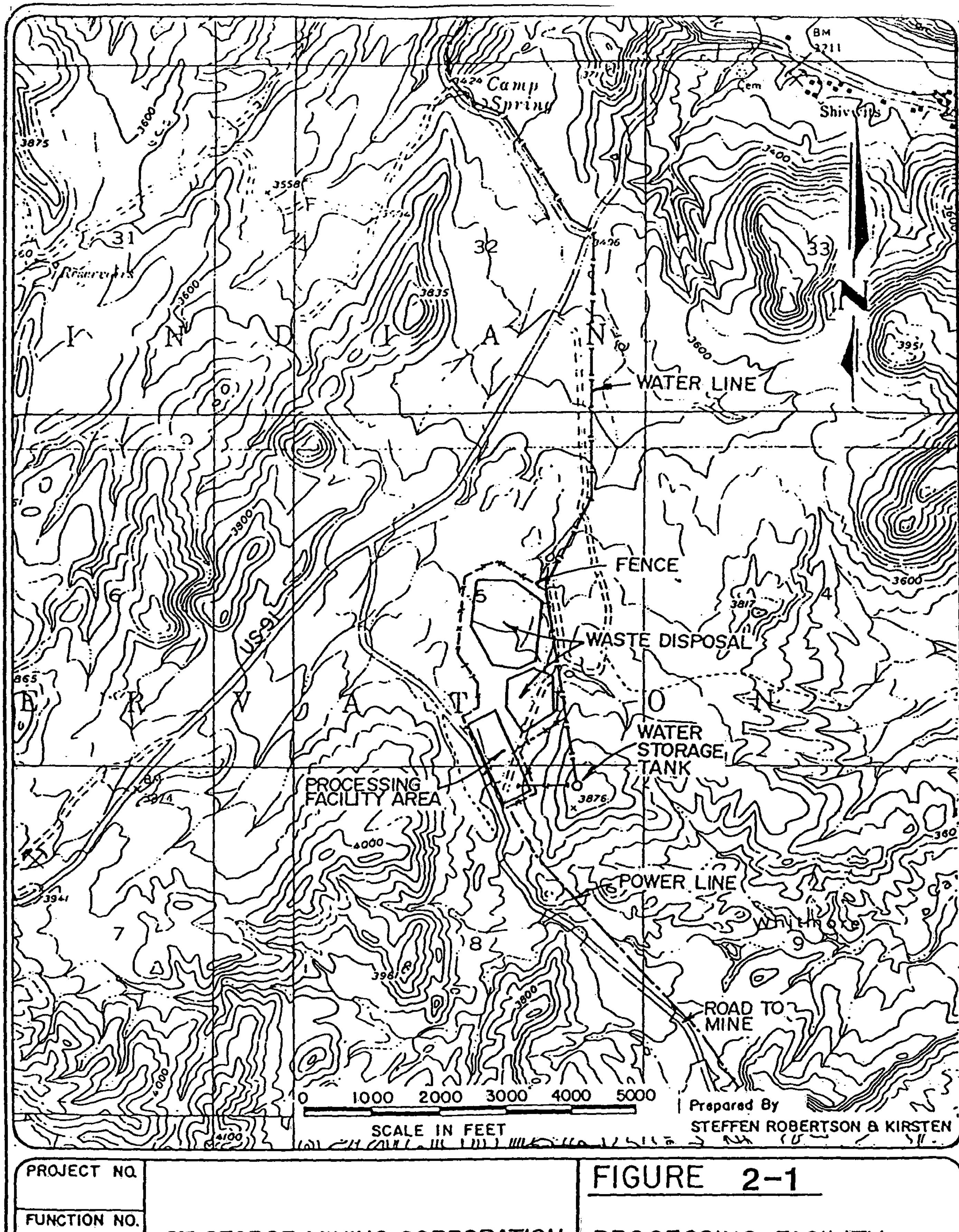
The dried product will be loaded into enclosed containers and shipped to a copper/zinc smelter for final processing. Minor quantities of silver are recovered from the off-site processing of the copper. The gallium and germanium are loaded into 55-gallon plastic-lined drums. The drums are sealed and shipped by truck for processing after accumulation of a full load.

The chemicals utilized as reagents historically in the processing of the ore are listed in Table 2-1 and include acids, bases, ammonia, hydrogen sulfide, iron, sulfur, flocculents, kerosene, an alcohol, and other extraction solvents. The on-site storage of chemicals is designed for a minimum of 10 days. All chemical storage and handling is designed to comply with Department of Transportation, OSHA, and MSHA regulations, and to follow guidelines provided by the Manufacturing Chemists Association and the National Tank Truck Carriers. Employees handling the reagents are given extensive training in the safe use and handling of potentially hazardous materials.

TABLE 2-1

CHEMICAL REAGENTS

Reagent	Annual Consumption	Shipping Method	Storage	Necessary Mitigating Procedures	Airborne Emissions
1) Sulfuric acid (93.3%)	14,280 tons	Tank truck 571 loads/yr	Steel tank	None	Trace amounts of hydrogen
2) Sodium chloride (94-96%)	9,648 tons	Covered dump truck, 240 loads/yr	Storage bins	Forms natural impervious crust	No airborne emissions
3) Molten sulfur	1,440	Insulated tank truck, 58 loads/yr	Steel tank	None	Minor non-hazardous fumes that condense and solidify at once
4) Caustic soda (50% NaOH)	408 tons	Insulated tank truck, 17 loads/yr	Heated steel tank	None	No airborne emissions
5) Hydrochloric acid (20% Be)	420 tons	Tank truck 18 loads/yr	Steel tank	Vented gas scrubbed with sodium carbonate	Trace amounts of sodium chloride, carbon dioxide, and water
6) Hydrogen sulfide	72 tons	Tank truck 6 loads/yr	Transport trailer	None	Minor emissions three times per year
7) Anhydrous ammonia	492 tons	Tank truck 20 loads/yr	Steel tank	None	Minor amount vented when making or breaking connections with tank
8) Sodium carbonate	360 tons	Hopper trailer 18 loads/yr	Transport trailer	Dust collecter on storage bin vent	No airborne emissions
9) Iron powder	645 tons	Flat bed trailer 21 loads/yr	55 gal. drums in warehouse	Transport and store in steel drums	
10) Solvent extraction amine	74 gal.	Flat bed trailer 1 load/yr		None	
11) Solvent extraction isodecanol	77 gal.				
12) Solvent extraction kerosene	619 gal.				
13) Sodium chlorate	10 tons			Transport and store in steel drums	
14) Flocculants	3 tons			None	
15) Gasoline	5,000 gal.	Tank truck 1 load/yr	Underground storage tank	Minimize fumes via underground storage	Will vent to atmosphere and dissipate
16) Diesel fuel	19,200 gal.	Tank truck 3 loads/yr	Same as above	Same as above	Same as above



PROJECT NO.	ST GEORGE MINING CORPORATION	FIGURE 2-1
FUNCTION NO.		PROCESSING FACILITY LOCATION MAP
REVISION NO.		

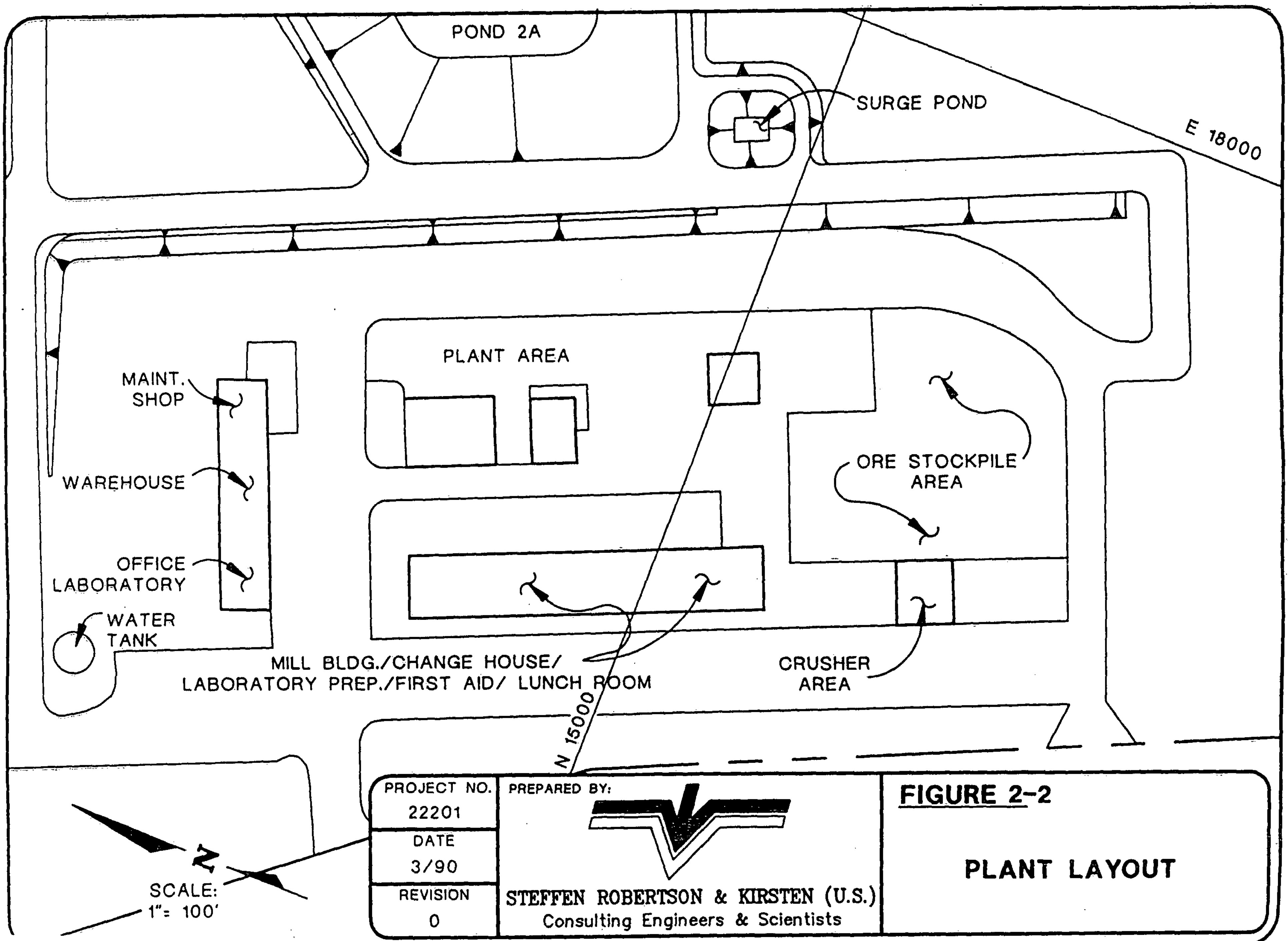
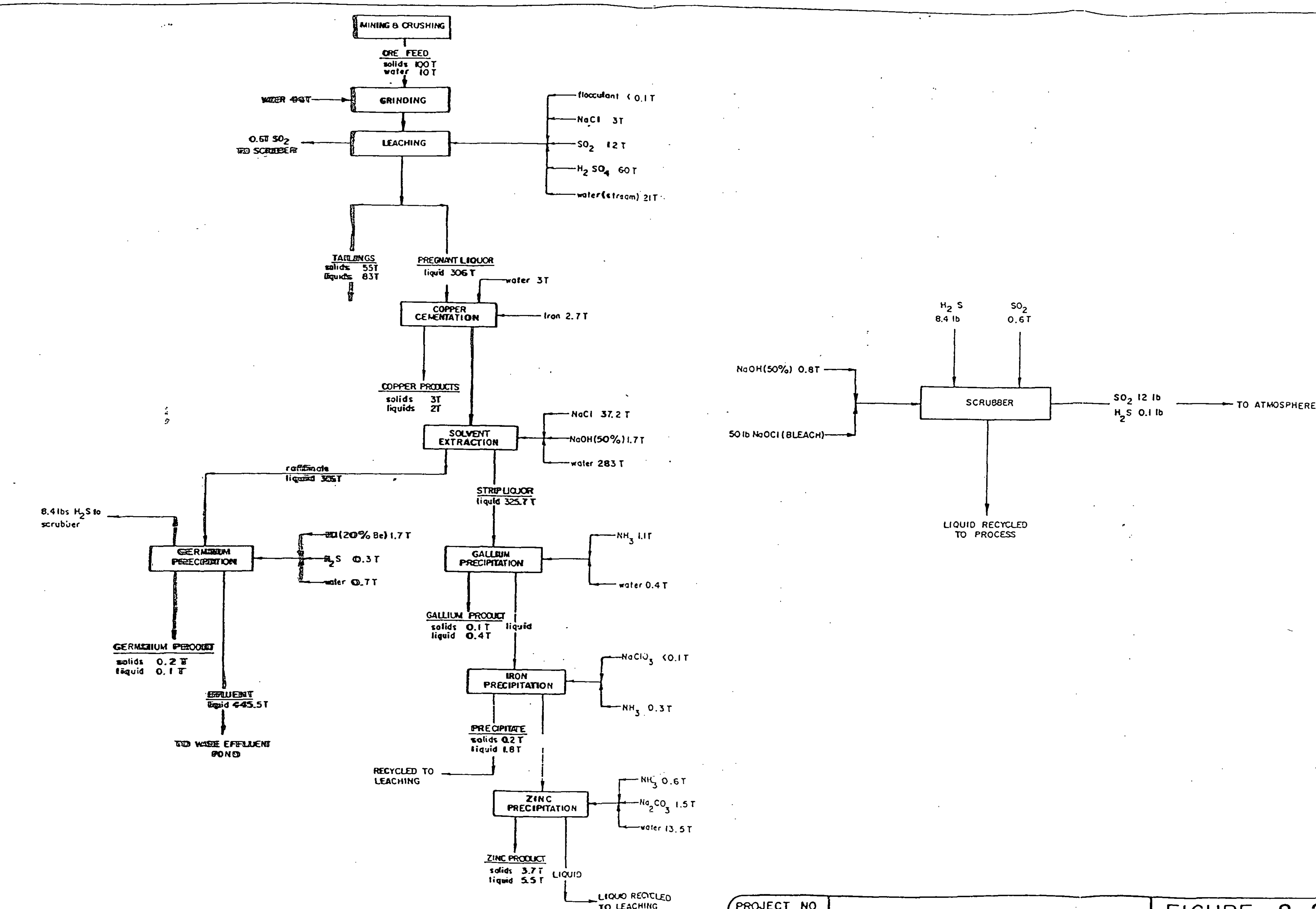


FIGURE 2-2

PLANT LAYOUT



PROJECT NO.	ST GEORGE MINING CORPORATION	FIGURE 2-3
FUNCTION NO.		GENERAL PROCESS FLOW SHEET & MATERIAL BALANCE
REVISION NO.		

PRELIMINARY WASTE DISPOSAL
FACILITIES DESIGN REPORT
APEX MINE

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1.0 INTRODUCTION

1.1 General

Hecla Mining Corporation (HMC) is currently redeveloping the Apex Mine in Washington County, southwestern Utah. The mine is located approximately 12 miles west of St. George, Utah (Figure 1).

The project will involve resuming the underground development of the Apex Mine and ore processing. The ore will be processed for extraction of gallium and germanium and lesser amounts of copper, zinc, and silver. The projected processing rate is 100 tons per day for a period of 13 years.

1.2 Scope of Report

HMC contracted with Steffen Robertson and Kirsten (U.S.), Inc. (SRK), to perform several tasks related to the redevelopment of the project. This report deals with the evaluation and design of a containment system for wastes produced in the metal extraction process. Two ponds have been evaluated for project startup and subsequent waste containment areas identified. The scope of this report contains a discussion of site conditions, waste characterization, and the containment capability of the pond systems designed.

1.3 Available Information

The preliminary design of the waste impoundment facilities was based upon the following information:

- Physical data on the project site area from published literature. This included geological, seismic, climatological, soils, and vegetation data;

- Mill process data from flow sheets supplied by HMC; and

- Physical data from the site from previous data, developed by SRK. This included geotechnical, geological, vegetation, climatic, and wildlife data;

- Site reconnaissance and survey information developed by SRK and HMC in following acquisition of the property; and

- Waste classifications and evaluation data developed by HMC.

2.0 PROJECT DESCRIPTION

2.1 Project Location

The project area is located in the southwest corner of the state of Utah, approximately 12 miles west of the city of St. George and approximately 80 miles northeast of Las Vegas, Nevada (Figure 1). The mine lies immediately east of the crest of the Beaver Dam Mountains at an elevation of 5,600 ft in Township 43 South, Range 17 West, Sections 6 and 7; and Range 18 West, Sections 1 and 12. The mining property consists of 22 patented and 9 unpatented mining claims owned by Hecla Mining Corporation (HMC). The processing site is located approximately seven miles north of the mine via county road and 1/2 mile south of State Highway 91 within Township 42 South, Range 17 West, Section 5.

2.2 Past Operations

The Apex mine was the most productive of several copper mines in the Tugsagubet mining district in the Beaver Dam Mountains of southwestern Utah (Utah Geological Mineralogical Survey, 1964). Mining in the district started in the 1870's. Mining in the Apex mine (originally known as the Dixie Mine) started before 1900, and continued intermittently until the end of World War II, producing approximately 100,000 tons of ore during the period. Ores from the mine were transported to St. George or more distant locations for processing. The old mine workings consist of two adits, eight levels of tunnels, and an inclined and a vertical shaft. The mine was developed to a depth of 1,440-ft below the vein outcrop. The presence of significant amounts of gallium and germanium in the Apex ores was recognized in the 1950's.

St. George Mining Corporation (SGMC) began conducting feasibility studies of extracting gallium, germanium, copper, zinc, and silver from the Apex ore in April 1982. In 1984, SGMC constructed a mill and tailings disposal facilities approximately seven miles north of the mine site on the Shivwits Indian Reservation. Production began in 1984 and continued until late in 1988.

At the end of SGMC operations, the waste containment system on the site consisted of eight ponds containing various amounts of solution and solids.

HMC acquired the property in 1989 with the intent of revising and resuming operations to extract gallium and germanium from the ores. By-product copper, zinc, and silver will also be produced.

As part of the proposed operations, HMC will reprocess the historic wastes currently on the property and utilize the waste areas for additional waste disposal.

2.3 Proposed Operations

The proposed operations for the Apex Mine consist of redevelopment of the underground mine and re-habilitation of the 100 ton per day mill. It is anticipated that up to 320,000 tons of ore will be processed over a period of 13 years.

Milling will produce tailings and raffinate as waste products. The waste impoundment facilities have been designed to contain these wastes in an economic and environmentally acceptable manner.

3.0 SITE DESCRIPTION

3.1 General

The mill and waste impoundment facility is situated in a broad valley at an elevation of approximately 3,700 ft (Figure 2).

The mine and waste impoundment site are both on the eastern slope of the Beaver Dam Mountains in an area that drains generally to the east towards the Santa Clara River, a tributary of the Virgin River. The topography to the east is typical of the Colorado Plateau region with smooth highlands and deeply-cut river valleys. The topography to the west is typical of the basin-and range regions of Nevada and eastern California with rugged highlands and wide, gently sloping lowlands.

3.2 Climate

The climate of the project site is characteristic of arid areas with light precipitation and high temperatures, with these parameters varying with elevation. The available climatological data closest to the site is from St. George where data was collected during the summer months of 1971 through 1976. This data is summarized in Appendix D.1. Because of the limited period for which this data has been collected and the variation in climate between the site (elevation 3,700 ft) and St. George (elevation 2,760 ft), climatological parameters for the design were developed by conservatively applying regional data to the site. The development of this data is discussed in Appendix D.1, and the major parameters are summarized as average annual values below.

Precipitation	10.0 inches
Class A pan evaporation	85.0 inches
Lake evaporation	56.0 inches
Net lake evaporation	46.0 inches

The lake evaporation was determined from pan evaporation by using a pan coefficient of 0.66. Monthly average values of evaporation were determined from regional data and checked with the data measured in St. George (Appendix D.1).

3.3 Geology

The assessment of the geology of the mill and waste impoundment site was made based upon the following information:

a. Review of available geologic literature;
b. Interpretation of available aerial photography;
c. Regional field reconnaissance;
d. Geologic mapping of the site; and
e. Subsurface drilling and excavation.

The details of the assessment of the sites originally conducted for the previous mine operator are presented in Appendix A.3, and are briefly summarized in this subsection.

3.3.1 Regional Geology

The site is located on the eastern flank of the Beaver Dam Mountains and is approximately 25 miles west of the Hurricane Fault (Figure 3). The Hurricane Fault is a major fault in the region and is considered to be the boundary between the Colorado Plateau and Basin-and-Range physiographic/tectonic provinces.

The Beaver Dam Mountains are a north-south trending fault-block range composed of sedimentary rocks ranging in age from Cambrian to Miocene. These sedimentary rocks, ranging in thickness from approximately 11,000 to 13,000 ft, were deposited over a complex of Precambrian-age gneisses and schists. Quaternary-age basalt flows and cinder cones are present on the northeast flank of the range.

Bedrock in much of the area is covered by unconsolidated surficial deposits, including landslide debris, talus, colluvium, alluvium and alluvial fan deposits. The age of these deposits ranges from Pleistocene to Holocene, with younger deposits in modern drainages.

The Beaver Dam Mountains are bounded on the west by the Beaver Dam Wash fault and on the east by the Cedar Pocket Canyon-Shebit-Gunlock fault system (Figure 4). Paleozoic to Mesozoic sedimentary rocks within the fault block have been folded into north-south trending anticlines and synclines. This folding, the Beaver Dam Wash fault and the Shebit fault are suggestive of east-west Laramide compressional forces occurring in late Cretaceous to early Tertiary time. The Cedar Pocket canyon and Gunlock faults are suggestive of block faulting from Miocene into Quaternary time along pre-existing zones of structural weakness such as the Shebit fault zone.

3.3.2 Site Geology

The site is underlain by Triassic-age Moenkopi Formation bedrock. The Moenkopi Formation is a complex sequence of interbedded claystones, shales, limestones, and sandstones which may be divided into five geologic units (Appendix A.3). The broad, north-trending valley containing the site is underlain by red and gray, interbedded sandstones, siltstones, and limestones that may be part of the upper or middle members of the formation. The ridges on the east and west sides of the site are underlain by interbedded sandstones, shales, and limestones indicative of the Shnabkaib member of the formation.

The Moenkopi Formation members in the site area have been displaced by two north-south striking faults located at the edges of the valley (Figures 5 and 6). A normal fault bounds the east side of the site and forms the boundary between the Shnabkaib member to the east and the red and gray Moenkopi member to the west. The inferred, down-to-the-west displacement suggests that this fault is part of the Gunlock fault system. The Shebit reverse fault bounds the west side of the valley where the beds of the Shnabkaib member have been reversed over the red and gray Moenkopi member to the east.

Bedrock in the project area is covered by a relatively thin veneer of unconsolidated, surficial deposits of generally Pleistocene to Holocene age. Colluvium ranging in thickness from several inches to several feet covers much of the bedrock in the site area. The colluvium is unstratified and ranges in particle size from clays to boulders. Alluvial fan deposits are found at the base of steep drainages in the project area, and consist of gravelly, sandy silts, and clayey silts. Alluvial deposits are found in the moderately steep drainages in the project area, and generally contain less gravel than the alluvial fans. These deposits are moderately stratified and are interfingered with alluvium and colluvium.

3.4 Seismicity

The seismicity of the site has been investigated by a review of available literature, an earthquake data-file search within the project region, site reconnaissance and trenching.

3.4.1 Regional Seismicity

Generally, the site is located within a region of moderate seismic activity, Zone 2 (ER-1110-2-1806). Algermissen and Perkins (1982), in their work on probabilistic estimates of maximum bedrock acceleration due to seismic events, estimate the following for the area containing the project site:

- A peak ground acceleration of 16 percent of gravity (0.16 g) has a 90 percent probability of not being exceeded in 50 years; and

- A peak ground acceleration of 42 percent of gravity (0.42 g) has a 90 percent probability of not being exceeded in 250 years.

An earthquake data search was made within a 186 mile (300 km) radius of the site[1]. The earthquakes larger than Richter magnitude 6.0 are summarized in Table 1, as well as the events closest to the site. The earthquake epicenters from this search are shown in Figure 4, along with the general location of young faults in the region from Arabasz, et al, 1979.

Within the 186 mile radius of the site considered, most of the large magnitude seismic activity has occurred in an area of southwest Nevada, approximately 150 miles from the site (Figure 4). Closer to the site, an area of activity has been delineated approximately 25 miles northwest of the site in eastern Nevada (Figure 4). This activity includes a magnitude 6.1 event and two magnitude 5 events. Several events have been recorded in the immediate site area, including a magnitude 4.0 event approximately 14 miles from the site and an intensity IV event approximately 6 miles from the site (Table 1).

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[1]Performed by the National Geophysical and Solar-Terrestrial Data Center, NOAA, U.S. Dept. of Commerce, Boulder, Colorado.

TABLE 1

REGIONAL SEISMIC ACTIVITY SUMMARY[a]

EPICENTRAL LOCATION	DISTANCE FROM SITE (MI)	RICHTER MAGNITUDE	MAXIMUM INTENSITY[b]	RECORDING STATION[c]	DATE OF EPISODE
	LISTING BY MAGNITUDE				
Southwest Nevada	151	6.5	VIII	CGS	Mar 25, 1970
"	144	6.4	-	GS	Oct 28, 1975
"	144	6.3	-	GS	Dec 20, 1966
"	147	6.3	-	GS	Mar 14, 1976
"	147	6.3	VIII	CGS	Dec 19, 1968
"	149	6.3	-	GS	Feb 12, 1976
"	149	6.3	-	CGS	Apr 26, 1968
"	140	6.2	-	GS	Jan 3, 1976
"	142	6.2	-	GS	Jun 26, 1975
"	147	6.2	VIII	CGS	Sep 16, 1969
Southeast Nevada	29	6.1	VI	USN	Aug 16, 1966
Southwest Nevada	139	6.1	-	GS	Mar 17, 1976
"	140	6.1	-	GS	Jun 6, 1973
"	142	6.0	-	GS	Nov 20, 1975
"	142	6.0	-	GS	Mar 9, 1976
"	144	6.0	-	GS	Feb 14, 1976
"	147	6.0	-	GS	May 14, 1975
	LISTING BY DISTANCE FROM SITE				
Southwest of site	6	-	IV	USE	Nov 20, 1955
East of site	11	-	VI	USN	Nov 26, 1920
Southwest of site	14	4.0	IV	USN	Dec 28, 1938
North of site	15	2.5	-	ERL	Jan 22, 1973
Northwest of site	20	5.1	IV	USN	Aug 18, 1966
"	20	5.0	VI	USN	Sep 22, 1966
Southeast of site	20	2.6	-	NOS	Dec 16, 1970
East of site	22	-	-	USN	May 3, 1944
North of site	24	4.1	-	CGS	Sep 1, 1970
Northeast of site	24	2.5	-	ERL	Nov 30, 1972
"	25	-	VIII	USN	Nov 17, 1902
Northwest of site	25	4.0	-	USN	Mar 6, 1943

[a]From data compiled by the National Geophysical and Solar-Terrestrial Data Center, NOAA, U.S. Dept. of Commerce, Boulder, Colorado.

[b]Modified Mercalli intensity scale.

[c]Sources of data: CGS - Coast And Geodetic Survey, GS - US Geological Survey, USN - US Network, USE - US Earthquake, ERL - Environmental Research Laboratories

3.4.2 Local Seismicity

Because of the "young" designation of the Cedar Pocket Canyon-Shebit-Gunlock fault system and the proximity of historical seismic events, a reconnaissance of faulting was undertaken in the immediate site area in conjunction with the geological investigation of the site. This work, documented in Appendix A.3, consisted of surficial reconnaissance and trench excavation across suspected fault traces in the site area.

As described in Section 4.3.2, the site is bounded by two north-south striking faults of the Cedar Pocket Canyon-Shebit-Gunlock fault system at the eastern and western edges of the valley (Figures 5 and 6). No evidence of faulting was found through the central portion of the valley. The Shebit reverse fault bounds the west side of the valley and a normal fault characteristic of the Gunlock fault system bounds the east side of the valley. Surficial reconnaissance and trenching of these faults indicated the possibility of recent movement along the fault, although the date of movement could not be accurately determined (Appendix A.3). Because of the potential activity of these faults indicated by the preliminary investigation, the faults bounding the site were assumed to be part of the Cedar Pocket Canyon-Shebit-Gunlock fault system for design purposes and have been avoided in locating the project facilities.

The maximum peak ground acceleration expected at the site has been evaluated by the attenuation of the maximum credible earthquake on the Hurricane and Cedar Pocket Canyon-Shebit-Gunlock faults. The evaluation has used the empirical relationships developed between the length of an active fault and the maximum credible earthquake (MCE) along that fault (Housner, 1970). Based upon a fault length of 80 miles, the MCE for the Hurricane fault is approximately a Richter magnitude 7.5. For the Cedar Pocket Canyon-Shebit-Gunlock fault system, the MCE is approximately 7.0 (based upon a fault length of 25 miles).

Empirical relationships have also been developed for the attenuation of seismic accelerations (Seed, et al, 1969; Schnabel and Seed, 1973) which for a site 25 miles from the Hurricane fault indicate that the peak ground acceleration in rock expected from a magnitude 7.5 event is approximately 25 percent of gravity (0.25 g). Similarly, the peak ground acceleration in rock expected 1/2 mile from a magnitude 7.0 event along the Shebit or Gunlock fault is approximately 0.70 g. The maximum credible peak bedrock acceleration at the site is therefore 0.70 g.

3.5 Geotechnical Conditions

The geotechnical characteristics of the site were investigated by shallow excavation, rotary drilling, soil sampling (Appendix A.2) and geotechnical testing (Appendix B.1). A plan of the location of the site investigations is given in Figure 6. The general stratigraphy of the site area is summarized in Figure 7.

3.5.1 General

As summarized in Section 3.3.2 the site consists of unconsolidated surficial deposits underlain by Moenkopi Formation bedrock. The geotechnical investigation was directed toward the surficial deposits and the upper bedrock layer of the site area.

3.5.2 Subsurface Materials

The bedrock at shallow depth in the site area and the overlying surficial deposits may be placed into the general material groups described below. The location of the groups encountered is shown in Figure 7 and their geotechnical characteristics are summarized in Figure 8.

a) <u>Group M - Moenkopi Formation Bedrock</u>. In the site area bounded by the fault traces, these materials primarily include weakly cemented, calcareous shales and fine-grained sandstones. Near the ground surface, these materials were excavated with a backhoe. The samples that were tested contained a considerable percentage of material finer than a No. 200 sieve (0.074 mm openings) ranging from 65 to 95 percent. The samples were generally classified as a low plasticity silt (ML) under the Unified Soil Classification System.

b) <u>Group E - Aeolian-Colluvial Deposits</u>. Much of the site area contains an upper layer of wind-blown surficial deposits of silt with small percentages of gravel and sand. The depth of this layer varies with location but is generally deepest in the low-lying areas (up to 7 ft) and is not present on ridges and high points. The sand and gravel in the soils indicate colluvial or alluvial deposition in addition to the loosely-structured aeolian silts. Samples of this material contained an average of 58 percent material finer than a No. 200 sieve (fines) and are classified as a low plasticity silt (ML). Although this group formed the upper layer of soil over much of the site, little development of horizons within this soil group could be identified. This soil has been mapped by the Soil Conservation Service (SCS) as a gravelly, sandy loam (Appendix C).

c) <u>Group C - Colluvial Deposits</u>. Beneath the Group E soils, a layer of silty, sandy gravel was encountered. This material contains some cobbles and the particles were generally angular to subangular, indicative of a colluvial origin. These materials contained zones of caliche of varying thickness and degree of cementation. Several of the calichified zones were sufficiently cemented to prevent excavation with a backhoe. Samples of these soils contained 21 to 24 percent fines and were generally classified as a silty gravel (GP).

d) Group A - Alluvial Deposits. Along the small ridge in the western portion of the site, a lens of silty, sandy gravels exists between the colluvial soils and the underlying bedrock (Figure 7). The particles are generally rounded, indicative of an alluvial origin. The limited extent of this deposit indicates that it may be an old alluvial channel. A representative sample of this soil contained 9 percent fines and was classified as a poorly-graded gravel (GP).

The sand to cobble-sized particles in all of the surficial materials consist of limestone, shale, and sandstone characteristic of the Moenkopi Formation sedimentary rock. The fine-grained fraction of the surficial soils exhibited low to non-plastic behavior.

Generally, there are two material groups which consist primarily of fine-grained materials. These are the aeolian-colluvial soils (Group E) and the mudstone members of the Moenkopi Formation (Group M). These fines are predominantly silt-sized and have a low plasticity.

The other two groups contain primarily coarse-grained soils. The colluvial soils (Group C) are generally well-graded and contain roughly 20 percent fines. These soils exhibit varying degrees of calcium carbonate cementation (caliche).

The alluvial soils (Group A) are not as well-graded as the colluvial soils and contain roughly 10 percent fines.

3.5.3 Construction Materials

The soils and rock described in the preceding section were used in construction of the waste disposal facilities. Due to the nature of these soils, containment was provided by the use of geosynthetic liner materials.

Following project completion, the waste facilities will be covered and reclaimed. The soils used in covering the facilities will provide the necessary isolation of wastes from the environment, as well as provide a seed bed and root zone for revegetation of the site. The aeolian-colluvial (Group E) soils are suitable materials for this effort. Selected members of the Moenkopi Formation may also be suitable for use as reclamation materials.

3.6 Surface Hydrology

The surface hydrology of the site area is characteristic of an arid region with light average precipitation but relatively high precipitation intensities and runoff. For a 25-year return period, the precipitation intensities for the 1-hour and 24-hour duration events are 1.80 and 2.90 inches, respectively (Appendix D.1.3).

The site is at the head of a small catchment that drains into the Santa Clara River (Figure 1 and 2). The Santa Clara River enters the Virgin River near St. George. The Virgin River is a tributary of the lower Colorado River. The Santa Clara and Virgin Rivers are the only perennial streams in the region.

The gaging station nearest to the site is on the Santa Clara River approximately 1/2 mile from Shivwits (Figure 1). The mean annual runoff for the region is approximately 1 inch.

Because of the absence of runoff data in the immediate site area, runoff was estimated by using the SCS hydrograph method and was checked with the rational method (Appendix D.2.1). The 25-year return period, 24-hour duration storm event was used for the development of precipitation intensities for design of surface water controls.

The catchment above the site contains steep slopes (up to 30 percent) composed of exposed limestone bedrock, as well as gentler slopes (as low as 2 percent) covered with soils of moderate permeability. Vegetation throughout the 124-acre catchment is sparse. In the runoff estimates, the catchment was represented by an average SCS curve number of 79 and an average coefficient of runoff of 0.40. Both estimation methods (SCS hydrograph and rational) gave similar results and yielded design values of 40, 40, and 80 cfs for peak flows in three sub-catchments above the site (Appendix D.2.1).

3.7 Geohydrology

The geohydrology of the site was investigated by studying published literature, consulting with investigators in the area, assessing the results of the geological investigation and the drilling of monitoring wells.

3.7.1 Regional Geohydrology

As described in Section 3.1, the site is on the eastern flank of the Beaver Dam Mountains. The eastern flank of these mountains consists of sedimentary rocks that generally dip to the east (Figure 4). Local variations in this pattern are the Shebit syncline and anticline systems and the Cedar Pocket

Canyon-Shebit-Gunlock fault system. The dip of the strata results in the exposure of older rocks to the west, such that Cambrian and Precambrian metamorphic and igneous rocks are exposed along the western land of the range (Figure 4).

Aquifers in the region include groundwater in unconsolidated, alluvial sediments in the Virgin River Valley and Castle Cliff area and in consolidated sediments north and east of St. George. The consolidated sediments are primarily Triassic to Jurassic sandstones and shales that are generally not present in the Beaver Dam Mountains because of the eastward dip of the strata.

Along the eastern flank of the Beaver Dam Mountains, the underlying strata primarily includes Triassic to Devonian limestones. Exceptions are the siltstone and sandstone members of the Moenkopi Formation (Triassic), and fine-grained, Supai-Coconino Formation sandstone (Permian). Aquifers along the eastern flank of the Beaver Dam Mountains are generally associated with fracture systems in the underlying limestones and fine-grained sandstones. This is confirmed by the presence of intermittent, low-yielding springs sparsely scattered along the eastern flank of the range which are associated with fracture systems. Seeps have been identified in the Apex Mine but are all of very low yield. In addition, well drilling along the eastern flank of the range has generally been unsuccessful in terms of the production of significant water supply.

3.7.2 <u>Local Geohydrology</u>

The site is underlain by strata of the Moenkopi Formation and subsequently by limestone and sandstone of Devonian to Permian Age. Two parallel, north-south trending Fault traces cross the site.

Groundwater was intersected in a fractured limestone aquifer at a depth varying between 280 and 360 ft. The aquifer appears to be confined, the groundwater being held under confined conditions shown by an increase in head of 30+ ft on intersection. The confining beds are mainly a hard, dense limestone or shale with interbedded, fine-grained sandstone. The base of the aquifer is formed by a very hard, unfractured limestone, so that the aquifer is hydraulically isolated both above and below in this area.

The general direction of groundwater flow is northeasterly and, although this gradient is towards the Santa Clara River, the lower limestone confining layer prevents direct hydraulic connection between the aquifer and the river. In the same way, any surface infiltration will essentially be prevented from reaching the limestone aquifer by in excess of 270 ft of overlying aquiclude.

The aquifer yield, determined by two, 24-hour constant discharge aquifer tests is moderate with the two boreholes, ASW-2 and ASW-3, yielding a total of between 75 and 100 gpm, assuming constant pumping. Details of the aquifer tests and the geohydrologic exploration program are given in Appendix A.1.

3.7.3 Groundwater Quality

Water quality samples taken during the aquifer testing program show the groundwater to be a poor quality, calcium-magnesium sulphate type as described in detail in Appendix A.1.5. The high total dissolved solids content of 3,000 mg/l renders the groundwater unsuitable for potable or domestic supply.

The 24-hour aquifer tests indicated that water quality in the limestone aquifer was homogeneous over a distance of some 2,000 ft and further drilling, therefore, in the area of the plant and tailings impoundment sites is unlikely to reveal water with significantly better quality in this aquifer.

3.8 Vegetation

The site vegetation was investigated by a review of literature and by on-site investigation. The details of this investigation are presented in Appendix C.

The vegetation at the site consists primarily of small shrubs of one predominant species (blackbrush). Juniper are sparsely scattered over the site area. Several species of annuals and herbaceous perennials are found beneath the shrubs after winter or spring precipitation. The vegetation found on-site is characteristic of the region. No rare or endangered plant species were identified during the site investigation.

The plant community on-site is that of a semi-arid climate with a low diversity of plant species. This is most likely due to overgrazing in the area.

3.9 Wildlife

Wildlife was identified through site investigation by visual sighting, tracks, and other sign, and is described in detail in Appendix C. The wildlife present on-site consists of both small mammals and birds with a limited range of movement, as well as larger mammals and birds that have a range that includes the site. Because of the absence of surface water and the similarity of the site soils and vegetation with those within the surrounding region, disturbance of the site should not adversely affect wildlife.

4.0 PROCESSING FACILITY

4.1 General

The mill and existing waste disposal ponds are located 12 miles west of St. George, Utah, and 0.5 miles south of State Highway 91. The site shown on Figure 2 lies in a broad valley at an elevation of about 3,700 ft.

The processing plant and disposal facilities are located on the eastern slope of the Beaver Dam Mountains at the head of a small catchment. About 100 acres will be affected by the processing facility, including 15 acres of the mill and 85 acres for the tailings disposal ponds and related structures. The existing and proposed facilities layout is shown on Figure 9.

The Apex Mine is designed as a 100 tpd operation and will process about 312,000 tons during the 13 year mine life. The processing plant shown on Figure 2-2 will operate 24 hours per day and five days per week. The mining and processing operations are scheduled to begin in the second quarter of 1990.

4.2 Extraction Process - **TO BE REVISED**

In the new process, the ore will be delivered to the plant by truck and stored in a run-of-mine stockpile about 250 x 250 ft in size. The ore will be delivered in a moistened form to control fugitive dust emissions. Ore from the stock pile will be transferred by front-end loader into a hopper and stored in a fine ore bin. The ore will then be fed into a ball mill and wet-ground to 35 mesh.

The ground ore will be leached in three countercurrent stages at 80°C with sulfuric acid, sodium chloride, and sulfur dioxide. The pregnant leach solution will contain about 20 g/L chloride at a pH < 1.0. The leached residue will be washed in three countercurrent decantation stages with a barren recycle solution, obtained from the zinc thickener overflow.

Copper will be precipitated from the leach solution by adding iron powder in three stages. The majority of the soluble lead and arsenic are precipitated with the copper. The chloride levels in the concentrated discharge are further increased to three molar by the addition of sodium chloride. The gallium and zinc are extracted by a tertiary amine and solvent, and stripped by dilute sulfurous acid. The sulfurous acid is a by-product of the sulfur dioxide generation process. The product strip solution will contain gallium, zinc, and a small quantity of iron. The three metals are then separated by a differential precipitation process. Gallium is precipitated first by adjustment of the solution pH to 5.0. The iron is then precipitated through oxidation at a pH of 4.0. Finally, the zinc is precipitated by raising the pH of 7.5 using ammonia and sodium carbonate or soda ash.

The germanium in the solvent extraction raffinate is precipitated by the addition of hydrogen sulfide to form a low grade precipitate. The precipitate is dissolved in an oxidizing hydrochloric acid leach, using sodium chlorate as the oxidant. The germanium is solubilized as a chloride, which is distilled from the pulp by heating to 104°C. The germanium in the distillate is hydrolyzed by neutralization with ammonia, forming germanium hydroxide and oxychloride. A simplified flowsheet of the process is presented on Figure ___.

The process will generate approximately 806 tons/year of cement copper, 980 tons/year of zinc hydroxide, 61 tons/year of a 32 percent germanium concentrate, and 44 tons/year of a 25 percent gallium concentrate. The cement copper and zinc hydroxide will be spread onto concrete pads and air dried to ten percent moisture.

The dried product will be loaded into enclosed containers and shipped to a copper/zinc smelter for final processing. Minor quantities of silver can be recovered from the off-site processing of the copper. The gallium and germanium will be loaded into 55-gallon plastic-lined drums. The drums will be sealed and shipped by truck for processing after accumulation of a full load.

The chemicals utilized as reagents in the processing of the ore are listed in Table 2 and include acids, bases, ammonia, hydrogen sulfide, iron, sulfur, flocculents, kerosene, an alcohol, and other extraction solvents. The on-site storage of chemicals is designed for a minimum of ten days. All chemical storage and handling is designed to comply with Department of Transportation, OSHA, and MSHA regulations, and to follow guidelines provided by the manufacturing Chemists Association and the National Tank Truck Carriers. Employees handling the reagents will be given extensive training in the safe use and handling of potentially hazardous materials.

4.3 Existing Wastes

4.3.1 General

A variety of chemicals and processes were employed in the production of copper, zinc, gallium, and germanium. The processing yielded two individual waste streams; a leach tails and a raffinate. Both were characterized by low pH, high acidity, elevated metals levels, and total dissolved solids concentrations. The proposed treatment of the two waste streams involved lime neutralization to a basic pH to facilitate precipitation of the metals, followed by disposal of the neutralized slurries in lined waste disposal ponds.

The slurries once disposed of in the ponds were to consolidate further through evaporation. The degree of drying

Table 2

TO BE COMPLETED UPON RECEIPT OF NEW PROCESS INFORMATION

and consolidation has been affected by the waste chemistry and the quantity of solutions contained in the ponds. As a result, the ratio of solution to solid has varied over time, as well as has the concentrations of various constituents within the wastes.

During the previous mine closure, the solutions and solids contained in the plant were placed in the containment ponds. Hecla Mining Company, upon reopening of the facility, made the commitment to retreat the solutions and solids, upgrade the existing disposal ponds, and encapsulate the redeposited and treated waste. In order to investigate and to select viable treatment programs and processes, a physical and chemical characterization of the existing waste was conducted.

4.3.2 Quantities of Existing Wastes

The previous mine closure resulted in deposition of wastes in eight containment Ponds; 1B, 1C, 2, 2A, 3A, 3B North and South, and the Surge Pond (Figure 9). Approximate waste quantities and waste type, solid or liquid, as of April 14, 1989 are given on Table 3.

During the summer of 1989, waste from pond 3A was transferred into Ponds 3B North and South, waste from the Surge Pond was transferred into Pond 2, and waste from Pond 1B was also transferred into Pond 3BN. The existing liners were removed from the emptied ponds and co-disposed with the process wastes. The foundation materials beneath each removed pond liner were tested for contamination.

A limited amount of soil beneath pond 3A was excavated and codisposed with the process wastes. Pond 3A was then relined with a double liner and leak detection system as presented in Section 6.2.3. The berm between Ponds 1A and 1B

TABLE 3

EXISTING WASTE QUANTITIES (SPRING 1989)

Pond	Approximate Waste Quantity (yd^3)	Waste Description
1A	0	Un-Lined
1B	500	Wet Crystals
1C	3,000	Wet Crystals
2	21,000	Dark Liquid[1]
2A	7,500	Dark Liquid[1]
3A	14,000	Brown Crystalline Sludge
3B North	4,000	Wet Crystals
3B South	4,000	Wet Crystals
Surge	1,000	Dark Liquid[1]

[1]Waste solution has the same appearance.

was removed to create one large pond, Pond 1A/B, which was relined with the double liner system.

In October 1989 the distribution of waste quantities by pond was resurveyed as given in Table 4.

4.3.3 Chemical Characteristics of Existing Waste

Samples of the solutions and solids contained in the various disposal ponds were collected on several occasions during 1988 and 1989 and submitted for geochemical analyses. The test results, presented on Tables 5 and 6, varied somewhat due to changes in solution concentrations and the ratio of solids to liquids which have varied over time. The actual analytical data sheets are contained in Appendix E.

In general, the wastes can be described as having low pH and elevated levels of arsenic, copper, iron, and zinc; and moderate levels of cadmium, lead, nickel, chromium, cobalt, manganese, and molybdenum. Low or non-detectable levels of barium, selenium, silver, and mercury were found.

4.4 Process Wastes TO BE REVISED

4.4.1 General

The benefication process involves crushing and leaching of the ore and extraction and precipitation of the leachate to produce concentrates of gallium and germanium, zinc, copper, and silver. A generalized schematic of the process is shown in Figure ___.

The processing plant is designed to operate at a rate of 100 tpd and is scheduled to be operated for 240 days per year. Two waste products result from the process. These are a leach

TABLE 4

DISTRIBUTION OF EXISTING WASTE (FALL 1989)

Pond	Waste Volume (yd^3)
1C	6,040
2	40,100
2A	3,500
3BN	2,700
3BS	2,200

Note: Refer to Figure 9 for pond designations.

TABLE 5

SUMMARY OF THE NOVEMBER 1988 WASTE CHARACTERIZATION

Parameter[1]	Pond							Surge Pond
	1B	1C	2	2A	3A	3BN	3BS	
pH	4.37	0.24	0.95	1.23	1.48	1.70	1.14	0.01
Arsenic	3.05	11,800	720	263	218	32.5	53.5	3,350
Barium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium	1.05	221	19.8	3.78	2.59	0.95	4.43	22.6
Chromium	<0.2	3.3	7.4	7.6	37.0	12.1	40.5	1.5
Copper	0.51	8,210	1,170	334	97.6	6.05	4.48	3,190
Lead	<1.0	63.0	5.0	4.0	1.0	<1.0	0.08	3.0
Mercury	<0.005	0.027	<0.005	<0.005	<0.005	<0.005	<0.005	0.027
Selenium	<0.1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Silver	<0.05	0.06	0.10	<0.05	<0.05	<0.05	<0.05	0.07
Total Organic Carbon	16.0	140	490	150	210	<69.0	190	190

[1] All analyses reported as total metals in mg/L, except pH.

TABLE 6

SUMMARY OF JULY 1989 WASTE CHARACTERIZATION

Pond Sample Identification	Parameter [1,2]										
	Fe	Ag	Cu	Ni	Mg	Ca	Pb	Zn	Na	Hg	As
3BS-1 liquid	53,000	0.25	12.1	820	12,800	32	2.6	10,250	53,000	0.007	89
3BN-1 liquid	48,000	0.26	9.0	172.8	11,300	26	2.8	9,360	33,000	0.003	220
1C-1 liquid	11,900	0.36	11,670	39.4	2,600	2.2	100.0	34,200	134,000	0.011	42,400
2-1 liquid	58,000	0.58	3,620	176.0	11,100	26	12.5	9 790	34,000	0.007	1,700
2A-1 liquid	48,000	0.24	770	104.6	5,500	36	7.0	4,770	17,000	0.002	480
Surge-1 slurry	6,000	0.30	7,610	1,289	1,500	1.7	2.7	3,210	12,000	0.005	12,000
3A slurry-1	58,000	0.22	151	99	3,100	49	1.9	3,060	4,970	0.001	98
3BS slurry-1	59,000	0.22	18.2	142.3	4,700	72	1.9	4,540	3,410	0.001	4.2
3BN slurry-1	69,000	0.26	69	102	5,200	123	2.3	3,700	1,560	0.001	11.0
1C slurry-1	1,700	0.32	3,020	18	270	63	60	4,500	100,000	0.009	2,100
1B slurry-1	239	BLD	2.6	12	100	422	1.1	2,930	11,000	0.0005	0.38

Pond Sample Identification	Parameter							
	Chloride	COD	Nitrate-N	Nitrite-N	Cd	Cr	Mn	Se
3BS-1 liquid	1,325	5,800	2.0	6.0	9	72.0	540	>0.02
3BN-1 liquid	2,873	6,300	26	4.0	10.7	85.0	540	0.02
1C-1 liquid	182,300	5,200	72	>2.0	440	7.0	147	0.20
2-1 liquid	11,220	8,700	7.0	8.0	58.99	17.0	13.2	0.28
2A-1 liquid	6.0	6,500	2	2	8.9	19.0	150	0.06
Surge-1 slurry	2,944	2,400	<2	<1	65.6	31.0	31.0	<0.002
3A slurry-1	1,094	7,000	<2	<2	4.4	22.0	170	0.120
3BS slurry-1	108	2,800	<2	3	1.7	5.0	74.0	<0.02
3BN slurry-1	395	6,300	<0.02	3	4.5	6.0	103	<0.2
1C slurry-1	40	600	<2	<1	174	1.1	16	<0.02
1B slurry-1	2,142	2,400	17.0	<1	1,085	<0.05	4.0	<0.2

[1] All values are total analyses expressed in mg/L.
[2] BLD is below the detection limit of the Apex Mine Analytical Laboratory.

tailings and a brine solution (raffinate). A tabulated summary of the anticipated production rates of waste is given in Table 7.

TABLE 7 MATERIAL QUANTITIES

	Material Quantities (tons)	
	Annual	Mine Life
Ore	24,000	312,000
Leach tailings slurry	33,000	429,000
Leach tailings solids	13,200	171,600
Leach tailings supernatant fluid	14,175	184,275
Raffinate	92,400	1,201,200
Crystallized raffinate	46,390	603,070
Free water in brine	46,010	598,130
Total free water	60,185	782,405

4.4.2 Tailings

Following leaching of the ore, the leached residue or tailings will be washed and neutralized. The tailings will have the gradation of a sandy silt and will exhibit the characteristics of a low-plasticity silt. The tailings have a specific gravity of approximately 2.85. The tailings are anticipated to have a pH of approximately seven (neutral) and will contain high concentrations of sulfates and chlorides.

The tailings will be slurried for hydraulic transportation to the disposal facility. The slurry is anticipated to contain 40 to 60 percent solids by weight. The tailings are estimated to be produced at a rate of 55 tons of solids per day.

Because of the salinity of the tailings, the particles will settle in a highly flocculated structure if deposition occurs under water. This could result in initial dry densities for the material as low as 45 pcf. However, if deposition can be performed in a manner such that a beach of tailings is developed to a limited pond of free water, initial settled densities of the order of 75 pcf can be anticipated. With the effects of consolidation under self-weight densities up to 90 pcf may result.

4.4.3 Raffinate

A brine solution, raffinate, will be produced in the germanium precipitation process. This solution will have the consistency of a viscous fluid. The raffinate will be acidic with a pH at or slightly less than 2. The anticipated milling rates will result in approximately 445.5 tons of raffinate per day of which approximately half is free water. The raffinate will be neutralized as presented in Section 5.2.2 and then pumped to the disposal ponds where the free water will be evaporated to produce a crystalline waste.

The brine will contain high concentrations of chlorides, sulfates, and iron. The brines will crystallize as free water is evaporated to produce a material with the gradation of a medium sand. Evaporation is affected by the concentration of salts within the fluid. At concentrations sufficient for crystallization to occur, evaporation may be as low as 55 percent of the equivalent evaporation of water (Appendix D). However, the specific gravity of the brine will increase as the concentration of salts increases. This will produce a density gradient within the pond with the highest concentrations at its base.

The development of crystals is anticipated to occur beneath the surface of the pond. The deposition of the brine is therefore anticipated to produce a fluid overlying crystallized brine. The average density of the brine and crystals will depend upon the volume and salinity of the fluid within the pond. Based upon the results of crystallization tests, it is anticipated that an equivalent waste dry density of 60 pcf will result.

5.0 WASTE DISPOSAL

5.1 General

The disposal methodology and design of the waste disposal facilities is intended to produce a neutralized, chemically stable, solid waste which can be permanently disposed of on site with no negative impacts to the environment. The design of the facility will allow for co-disposal of the existing wastes and new process wastes. In order to minimize the required pond capacities, the wastes will be disposed of in the densest condition as is practical.

5.2 Process Wastes **TO BE REVISED**

The treat waste will be transported and deposited into the waste disposal ponds as a slurry containing 40 to 60 percent solids by weight. The treatment process will produce lime stabilized slurry containing a large percentage of gypsum. Water in the slurry will be bound with the gypsum and will include limited free water. The solid particles will settle out of the slurry resulting in a solid waste and a pool of free water. The water pool will then be decanted and/or evaporated to leave only the solid waste.

Because of the salinity of the waste, the particles will settle in a highly flocculated structure if deposition occurs under water. This could result in initial dry densities for the material as low as 45 pcf. However, if deposition can be performed in a manner such that a beach of waste is developed to a limited pond of free water, initial settled densities of the order of 75 pcf can be anticipated. Deposition of the slurry in thin layers will facilitate maximum consolidation and dewatering. Deposition in alternating ponds may be required to result in thin layers of freshly deposited waste. With the effects of consolidation under self-weight, ultimate densities up to 90 pcf may result.

Due to the limited pond area over which evaporation can take place, the waste will be deposited in the ponds with the least amount of water in the slurry as is practical. If evaporation of free water alone is insufficient to achieve the desired results, mechanical dewatering may be utilized to assist the drying and desification processes. Dewatering most likely would consist of mechanical filtration or decanting the free water pool by pumping .

5.3 Existing Waste

5.3.1 General

Due to the low pH and elevated levels of metals contained in the existing wastes, it was determined that they would require treatment prior to final disposal. In order to determine the level of treatment required, elimination of EP metals toxicity was utilized as a primary guideline. The metals of major concern included arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Of secondary concern were the constituents of iron, manganese, nickel, zinc, selenium, TOC, chloride, sulfate, TDS, conductivity, pH, ammonia-N, nitrate-N, and nitrite-N.

Based upon experience, the best available treatment option involved neutralization with base, with or without the addition of coagulants, precipitation reagents, or encapsulants. A series of test programs were designed and conducted to evaluate various treatment alternatives.

The test program was divided into three phases. The first phase involved a preliminary neutralization study employing lime alone. The second phase involved an investigation of several treatment approaches using composite waste samples, lime coagulants, and cement. Both Phases I and II included an evaluation of the EP Toxicity of the treated waste samples. The third phase of the program involved an examination of the chemical stability of the treated wastes through column leach evaluations.

5.3.2 Treatment and Neutralization

Lime was selected as the preferred treatment reagent since it is an easily obtainable chemical in bulk form and has been proven effective in the precipitation of metals. The basic process chemistry involves raising the pH of the waste to 10.5 with lime to yield insoluble and stable metal complexes. If the treated high pH waste is disposed of in a contained manner where contact with low pH solutions in minimal, the material will remain stable as long as the high pH is maintained. The EP Toxicity results demonstrate that lime addition alone results in an acceptable waste product, and addition of cement, sulfide, or iron coagulants is not required.

In order to treat the solid wastes and slurries, they were first solubilized. A minimum of 13.2 gallons of water was required to solubilize one cu ft of solid waste. It was found that one-step neutralization with lime resulted in a gelatinous mass which could not be stirred, creating a difficult handling situation.

To achieve adequate mixing and treatment, lime was gradually added to the liquid waste or solubilized solids as a 20 percent lime slurry to affect neutralization to a final pH of 10.5 to 11.0. The treatment studies also evaluated the use of cement as an additional stabilizing agent, ferrous sulfate and sodium sulfide were examined as potential metals removal reagents. The test results presented on Tables 8, 9 and 10, indicate that the toxicity of the treated material with regards to its EP Toxicity was eliminated, and that neutralization with lime alone was sufficient.

The test results presented in Table 8 represent a composite sample of the ponds containing solid wastes, Ponds 3A, 3BN, SBS, 1C, and 1B. The composite sample was composed of wastes from the various ponds mixed in the approximate ratios of the quantity of waste in a pond to the total waste volume. The composite sample consisted of 41 percent from Pond 3A, 23.7 percent from Ponds 3B North and South, 11 percent from pond 1C and 0.6 percent from Pond 1B. The test results presented in Tables 9 and 10 represent treatment of the liquid waste. The actual individual analytical data sheets are contained in Appendix E.

Neutralization required about 400 to 500 pounds of lime to neutralize 2,000 pounds of waste and employed a 2-hr neutralization period. As shown in Table 11, the initial volumes of the untreated wastes varied from 500 to 2,000 ml, which increased to 2,500 to 3,500 ml following addition of the 20 percent lime slurry. About 112 to 503 grams of lime were required to neutralize the untreated wastes. Ammonia evolved from the slurries at pH values of 8.4 and above. The specific gravity of the wastes before and after treatment ranged from 1.18 to 1.53 g/ml to 1.07 to 1.24 g/ml. The volume of the treated waste following air or oven drying varied from 970 to 1,600 ml (air) or 200 to 1,000 ml (oven). The percent solids following air drying ranged from 21 to 43 percent with an average of 20 percent solids.

In conjunction with the neutralization tests, additional studies were conducted by Hecla Mining to evaluate mechanical and air drying of the treated wastes. With regards to air drying it was noted that disposal of the slurry in shallow layers of 1- to 2-ft in depth could yield an acceptable

TABLE 8

RESULTS OF THE NEUTRALIZED COMPOSITE SAMPLE EP TOXICITY EVALUATIONS

Run	Parameter (ppm)								Condition
	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	
1	<0.002	0.02	0.318	<0.01	0.1	0.0006	<0.002	0.02	CaO only
2	<0.002	0.13	0.172	<0.01	<0.1	0.0006	<0.002	<0.01	CaO + 50g Cement
3	0.002	0.24	0.102	0.02	<0.1	<0.0002	<0.002	<0.01	CaO + 100g Cement
4	<0.002	0.36	0.090	<0.01	<0.1	<0.0002	0.002	<0.01	CaO + 200g Cement
5	<0.002	0.01	0.166	<0.01	<0.1	0.0008	<0.002	<0.01	CaO + 1g Ferrous Sulfate
6	<0.002	0.02	0.191	<0.01	<0.1	0.0002	<0.002	<0.01	CaO + 2g Ferrous Sulfate
7	<0.002	0.03	0.197	0.02	<0.1	0.0002	<0.002	<0.01	CaO + 5g Ferrous Sulfate
8	<0.002	0.03	0.259	0.01	<0.1	0.0002	<0.002	<0.01	CaO + 1/4g Sodium Sulfide
9	<0.002	0.01	0.209	0.01	<0.1	0.0004	<0.002	<0.01	CaO + 1/2g Sodium Sulfide
10	0.003	0.01	0.335	0.01	<0.1	0.0004	<0.002	<0.01	CaO + 1g Sodium Sulfide

Limits:

As	5 ppm	Cr	5 ppm	Se	1 ppm
Ba	100 ppm	Pb	5 ppm	Ag	5 ppm
Cd	1 ppm	Hg	0.2 ppm		

TABLE 9

ANALYSES OF THE NEUTRALIZED FILTRATES
LIQUID WASTES

Pond Sample Identification	Parameter (ppm)										
	Fe	Ag	Cu	Ni	Mg	Ca	Pb	Zn	Na	Hg	As
3BS-2 liquid	0.33	0.14	0.12	0.97	27.9	160	0.53	55	7400	<0.0005	0.029
3BN-2 liquid	0.23	0.1	0.07	0.50	100	880	0.28	3.6	19000	<0.005	0.092
1C-2 liquid	0.83	0.14	2.16	1.21	3.7	6920	1.17	0.6	36000	0.0035	1.50
2-2 liquid	0.19	BLD	2.49	0.25	20	670	0.11	0.1	8240	0.0005	1.1
2A-2 liquid	0.20	BLD	BLD	0.23	2.9	389	0.11	3.8	10000	0.0010	1.20
Surge-2 Slurry	BLD	BLD	1.73	BLD	0.31	720	0.1	0.2	1500	<0.0005	2.1

Pond Sample Identification	Parameter (ppm)							
	Chloride	COD	Nitrate-N	Nitrite-N	Cd	Cr	Mn	Se
3BS-2 liquid	818	345	<2	<1	<0.025	<0.05	<0.05	<0.01
3BN-2 liquid	3384	450	8.0	<1	<0.025	<0.05	<0.05	0.01
1C-2 liquid	63	4800	<2	<1	0.04	<0.05	<0.05	0.010
2-2 liquid	3592	620	3.0	<1	<0.025	<0.05	<0.05	0.050
2a-2 liquid	3606	360	<2	<1	<0.025	<0.05	<0.05	<0.01
Surge-2 slurry	586	185	<2	<1	<0.025	<0.05	<0.05	0.090

BLD - Below Limits of Detection

TABLE 10

RESULTS OF THE NEUTRALIZED LIQUID WASTE EP TOXICITY EVALUATIONS

Pond Sample Identification	Parameter (ppm)										
	Fe	Ag	Cu	Ni	Mg	Ca	Pb	Zn	Na	Hg	As
3BS-3 liquid	2.3	0.93	0.63	3.51	300	144	2.34	0.78	150000	--	0.022
3BN-3 liquid	1.0	0.15	0.48	0.72	225	937	0.81	1.14	6100	0.0005	0.091
1C-3 liquid	0.8	0.33	1.72	1.46	99	1011	1.66	2.20	120000	0.0015	0.970
2-3 liquid	0.3	0.15	0.85	0.54	106	1032	0.88	0.36	19800	<0.005	0.110
2A-3 liquid	0.5	0.12	0.10	0.54	207	942	0.60	0.42	9300	0.0010	0.059
Surge-3 slurry	0.2	BLD	0.55	BLD	27	455	0.90	0.1	1225	<0.0005	0.71

Pond Sample Identification	Parameter (ppm)							
	Chloride	COD	Nitrate-N	Nitrite-N	Cd	Cr	Mn	Se
3BS-3 liquid	382	150	<2	---	---	---	---	---
3BN-3 liquid	624	140	3	<1	<0.025	<0.05	<0.05	0.010
1C-3 liquid	26	4270	<2	<1	<0.025	<0.05	<0.05	<0.010
2-3 liquid	2636	170	<2	<1	<0.025	0.35	<0.05	0.030
2a-3 liquid	1380	130	<2	<1	<0.025	0.35	<0.05	<0.010
Surge-3 slurry	158	260	<2	<1	<0.025	<0.05	<0.05	0.040

TABLE 11

NEUTRALIZATION TEST RESULTS

Pond Sample	3b South	3b North	1C	2	2A	Surge	3A Slurry	3B S Slurry	3B N Slurry	1C Slurry	1B Slurry
Start pH	0.81	0.78	-0.20	0.89	1.28	1.01	1.94	1.95	2.09	0.30	4.60
Final pH	10.57	10.70	10.67	10.62	10.52	10.83	10.97	10.52	10.54	10.80	10.51
Start Volume (ml)	2000	2000	1000	1000	2000	500	2000	2000	2000	2000	2000
Final Volume (ml)	3400	3450	3200	3200	2800	2950	3200	3400	3400	2500	3000
Start SG	1.38	1.38	1.31	1.31	1.23	1.53	1.24	1.24	1.25	1.29	1.18
Final SG	1.21	1.24	1.08	1.08	1.07	1.14	1.15	1.16	1.16	1.19	1.14
Volume to Sundry (ml)	1600	1632	971	971	1000	1604	1000	1000	1000	1000	1000
Volume Dried (ml)	1000	1000	200	200	850	870	450	550	425	400	250
Sludge % Solid	34	37	22	22	22	21	27	28	25	31	28
g/l of Lime to Neutralize Solution	214	194	163	163	114	503	112	118	129	60	115
Start EMF	+346	+357	+340	+340	+326	+371	+286	+282	+278	+372	+126
Final EMF	-112	-228	-218	-218	-211	-205	-254	-221	-218	-253	-182
Ammonia Stripping (pH)	8.5	8.5	8.26	8.26	8.69	none	8.50	8.50	8.50	8.5	8.39

percent solids. Preliminary tests indicated that drying could yield 70 percent solids. Disposal of the treated slurry in deep layers resulted in formation of a surface crust and virtually no dewatering of the deeper material. Several additional experiments are currently being conducted to further evaluate the air drying alternative. The results of the experiments are not currently available.

With regards to mechanical dewatering, a series of laboratory experiments were conducted by Hecla Mining to evaluate the use of disc filters to produce a highly dewatered solids cake for disposal. The preliminary results indicated that a filter cake containing 50 percent solids could be achieved. Dewatering of the wastes to 50 percent solids would significantly reduce the pond volume and surface area requirements for treated waste disposal.

5.3.3 Treated Volumes

The solid waste required solubilization initially, approximately 13.2 gallons of water were needed to solubilize 1 ft^3 or 110 pounds of solid waste (average density).

The total volume of waste requiring treatment is about 1,500,000 ft^3. If the waste is treated over a period of three years, six days per week, sixteen hours per day (two shifts), then about 1,600 ft^3 per day or 100 ft^3 of the wastes per hour must be treated. Assuming about 25 percent of the available time is utilized for start-up, shutdown, cleaning, and maintenance, the treatment period is reduced to 12 hours. Accounting for the time loss, the volume of waste requiring treatment increases to 134 ft^3 per hour, or about 250 pounds per minute. If 13.2 gallons of water is required to initially solubilize 110 pounds of waste, the volume and flow of water required during a twelve hour period is 21,600 gallons or 30 gpm. using the initial density for the solubilized waste of 1.28 g/ml or 10.7 pounds/gallon obtained in the laboratory, the initial waste flow including water is about 47 gpm. The initial volume following treatment and addition of the 20 percent lime slurry nearly doubles, based upon the laboratory results, to about 88 gpm. The calculation assumes a lime usage of 500 pounds/ton of waste.

The additional water introduced with the lime slurry is about 36 gpm, which added to the initial flow of 30 gpm yields of total water usage of about 66 gpm. The total quantity of lime required is about 44,000 pounds per day or 22 tons.

Assuming the waste dries to a final moisture of 70 percent, based upon the preliminary drying experiments, the quantity of water requiring recycle or evaporation is about 50 gpm. About 16 gpm of the water usage would be entrained in the solids. These values provide a basis for estimating the volume and surface area of ponds required for waste disposal.

Based on the above assumptions, the total pond capacity required for disposal of the existing wastes is approximately 1.85×10^6 ft^3. Based on the evaporation data presented in Appendix D, the total area required for evaporation of excess water contained with the treated and disposed existing waste, assuming no mechanical dewatering of recycling of water, would be approximately 10.3 acres.

5.3.4 Chemical Stability

In conjunction with the EP Toxicity tests, a series of long term column leach studies were conducted to evaluate the potential chemical impacts of leachate from the treated waste entering the underlying soils. The column leach studies presented in this section were performed to estimate the potential seepage quality. It is not the intent to imply that seepage from the facility will occur, but merely to examine the seepage quality.

The tests involved placing neutralized and treated waste samples in a column directly above native soil samples. Distilled water was then percolated through the two materials, and the first nine pore volumes collected. A blank was obtained using natural soils and distilled water only. The results.of two initial column leachate studies are presented in Appendix G, along with a description of the test procedures. The results indicated that no significant leaching of heavy metals occurred and no exceedences of the EP Toxicity criteria were noted.

However, very high concentrations of sulfate, chloride, sodium, and calcium were noted in the initial leachate, which decreased by an order of magnitude by the ninth pore volume. The potential impact of these elevated inorganic levels on deep groundwater and the permeability of the soils has not been addressed. Further column leach studies are being conducted and the final results are not currently available. Additional studies are required to investigate the effect of the leach solution chemistry on the long-term permeability of the soils.

6.0 WASTE DISPOSAL FACILITIES

6.1 General

The waste impoundment facilities have been designed to comply with the environmental requirements affecting the project, as well as to be practical and cost-effective to construct, operate, and decommission. The design is based upon an evaluation of the site and the process wastes produced.

6.1.1 Regulatory Requirements

The projected waste characteristics for both the treated existing wastes and the new waste is indicated to be a non-hazardous material which will form a solid waste following deposition. The current federal guidelines for the containment and permanent disposal of non-hazardous solid waste have been incorporated in the recommissioned ponds (1A/B and 3A) and will be incorporated in the proposed future waste containments.

6.1.2 Environmental Requirements

The waste impoundment facilities have been designed as a closed system. The facilities have been designed such that the wastes will not adversely affect the surrounding air, surface waters, or groundwater.

The facilities will be lined to prevent seepage into and potential contamination of the subsoils. The facilities are capable of containing extreme precipitation storm events in addition to the anticipated waste quantities. Runoff from the catchment above the site will be diverted around the site.

In the unlikely event of a waste spill or leak in the liner, the soils and rock beneath the site have a buffering capacity that will chemically attenuate the waste constituents before they would reach groundwater located beneath the site. The attenuation capacity of the soils and rock beneath the site was evaluated by leach test procedures outlined by the EPA. The evaluation is described in Appendix G and indicates that the high calcium carbonate content of the substrata should chemically attenuate the majority of mobile constituents that may be generated by the wastes.

6.1.3 Design Criteria

Design criteria developed for the waste facilities were based upon the process anticipated for the project, and the regulatory and environmental requirements. These criteria reveal that the dual criteria of capacity for the wastes and area for evaporation of liquids is required.

The proposed development of the waste disposal is to construct the facilities in phases. The initial construction has been designed to meet the operating requirements for a minimum of 0.5 years. The principal design criteria during this period is that of providing storage capacity for the waste. During the initial operation of the facility, monitoring of the slurry density, free moisture, and entrained moisture in the waste will be performed. Subject to achieving acceptable density and evaporation of the free solutions the schedule for additional pond construction will be defined. For subsequent stages of development, the design criteria is one of providing adequate capacity for the total projected volumes of waste and adequate evaporative area.

The flexibility in developing the project in stages will allow verification or modification of the design for the subsequent stages.

Design of the hydraulic facilities associated with the project were based upon a 25-year storm event (Appendix D.1.3). The storm duration producing the most precipitation and runoff (24-hour duration) was used in the design. These hydraulic facilities are the diversion ditches around the waste impoundments.

With respect to the potential seismicity of the site, all facility embankments were located away from the mapped fault traces (Figure 6). In addition, the embankments are considered capable of withstanding loading induced by the maximum anticipated seismic accelerations of 0.7 g.

All of the waste facilities were designed with a synthetic liner system for seepage control.

6.2 Facilities Description

6.2.1 General

The waste disposal facilities are located to the north of the processing and storage area as shown on Figure 9. The facilities consist of lined impoundments formed by compacted earth fill embankments. The waste will be piped from the process plant into the impoundments. The surface runoff from the catchment area above the disposal facilities is intercepted by diversion ditches which route water around the facilities and downstream into the existing stream channels.

The following sections give a detailed description of the various parts of the facilities.

6.2.2 Runoff Control

Runoff from the catchment above the site will be diverted around the facilities by two diversion ditches which are shown on Figure D.2-1. These ditches will collect and convey the anticipated runoff around the facilities into the natural drainage below the site. One diversion ditch is located along the western edge of the site, and the other is located along the southeastern side of the site.

Runoff from the catchment will pass through a pond northeast of the site as shown on Figure D.2-1. This pond will serve as a sediment control structure, as well as a collection facility for makeup water at the mill if required.

6.2.3 Liner System

A synthetic liner system will be installed beneath all waste disposal impoundments. The liner system will provide an low permeability barrier to the seepage of the constituents of the waste. The liner system will consist of a 60-mil HDPE liner over which a geonet drainage grid and second 60-mil HDPE liner will be placed to form a double-lined system with a leak detection layered sandwiched inbetween. HDPE was chosen as the liner material due to its low permeability and chemical resistance. Review of the waste constituents and consideration of the concentrations of the various potentially reactive solutions with the waste (Appendix H) do not indicate concern as to the long-term chemical stability of the liner.

The choice of a synthetic leak detection layer was made from consideration of the constituents of the waste and the potential for precipitation within a porous media. The high transmissivity of the geonet will allow rapid detection of any leakage from the upper liner.

A foundation consisting of compacted subsoils was prepared beneath all liners. Details of the liner system are shown on Figure 10.

The permeability of the foundation is indicated to be approximately 10^{-5} cm/sec in proximity to the liner decreasing to approximately 10^{-6} to 10^{-7} cm/sec at depth.

The manufacturer's specifications and documentation for the proposed liner installation are presented in Appendix I.

6.2.4 Embankments

The embankments for the facilities have internal side slopes of 3:1 (horizontal:vertical) and external side slopes of 2.5:1. The liner will prevent the saturation of the fill. The embankments are composed of on-site materials consisting of a combination of the aeolian and colluvial deposits on site (Section 3.5). The embankments are compacted in lifts according to density and moisture content specifications to produce a minimum of 95-percent Proctor density to ASTM D698-78. Sections through the embankments are shown in Figures 9 and 10.

At the upslope perimeter of the impoundments, a berm will be constructed to function as an anchor for the liner and prevent runoff from entering the impoundments. The slope of the embankments and the unsaturated state of the fill material are considered to provide adequate stability for the embankments.

6.2.5 Rehabilitation of Existing Impoundments

The existing waste disposal impoundments will be upgraded through deepening and relining with a double synthetic liner system. The following is a general sequence in which the rehabilitation will be executed.

a. Existing wastes will be removed from the impoundment either by pumping (liquids) or excavation (solids). Excavation of solid wastes will be performed in a careful and controlled manner to prevent large tears and escape of wastes into the subsoils.

b. Portions of the existing liner which are encrusted with waste will be cleaned by high pressure washing or cut and removed.

c. A leak detection sump will be excavated into the floor of each pond. Details of the leak detection system and sump are presented on Figure 10.

d. All removed liner will be disposed of separately or in conjunction with the treated wastes. Washing may be required if disposed of in a separate on-site or off-site disposal facility.

e. In the case of liner removal or tearing, subgrade soils will be tested for waste contamination.

f. Any contaminated soils will be removed, neutralized or washed and co-disposed with the wastes in an active disposal impoundment or with removed liner in a separate facility.

g. In areas where the existing liner has been removed, the sub-grade materials will be worked to remove cobbles and larger gravel materials. Fine grained soils will be placed and worked into the upper few inches of the subgrade and compacted as per the project specifications (Appendix I).

h. The synthetic liner system will be installed over the prepared subgrade or old liner.

i. Tailings and raffinate delivery and distribution systems will be installed.

j. Initial deposition will begin.

Pond 1B and 3A were rehabilitated during the fall of 1989. Rehabilitation of Pond 1B consisted of removal of waste and liner, enlargement by combining with Pond 1A, and then relining with the double liner system. Rehabilitation of Pond 3A consisted of transferring wastes to Ponds 3B North and south, removal of existing liner, excavating and regrading of the pond and then relining of the entire pond with a double liner system. The total combined capacity of these two rehabilitated ponds is approximately 3.75×10^6 ft^3.

During deposition of wastes, the accumulation of waste will be monitored to evaluate the as-deposited densities and evaporation rates. This information will then be used to determine the ultimate pond capacities and the need for additional disposal capacity. Additional disposal impoundments will be constructed and brought into operation as required.

6.2.6 Construction of New Impoundments

The waste impoundment facilities will be constructed as a cut-and-fill operation where fill for the embankments will be excavated from within the impoundment areas. The following is a general sequence in which the construction new impoundments will be executed on an as-needed basis.

a. The site will be cleared and grubbed to the extent of the construction.

b. The soils required for reclamation will be stripped from the site and stockpiled.

c. Soils required for embankment construction will be stripped from the site and either stockpiled or placed directly in the embankments.

d. Diversion ditches will be constructed.

e. The impoundments will be shaped and embankments constructed.

f. The final impoundment surface will be smoothed and compacted for synthetic liner placement.

g. The synthetic liner system will be installed in the impoundments.

h. Tailings and raffinate delivery and distribution systems will be installed.

i. Initial deposition will begin.

6.3 Potential Environmental Impact

6.3.1 Air Quality

The waste disposal facility will not produce dust or odors. The waste will be kept in a moistened condition until reclamation. The exposed face of the embankments will be lined with bank protection to minimize water and wind erosion.

6.3.2 Water

6.3.2.1 Surface Water

The processing facilities are located at the top of a small catchment area. There are no streams or springs on the site. The nearest surface water is the Santa Clara River approximately 2.5 miles away.

The construction and operation of the processing facility should have minimal impact on the surface water of the project site and the vicinity. During construction, the ground surface will be disturbed by grading, excavation, road access, topsoil removal and storage, and other construction-related activities.

Erosion will be minimized by reseeding of disturbed areas, grading to control runoff velocities, and constructing dikes around topsoil stockpiles to cause ponding of rainfall. In addition, the entire area of the processing facility will be graded and shaped so that all runoff from undisturbed areas adjacent to the project site will be carried around and away from the site by diversion ditches and into the existing stock water pond. This pond will act as a sediment control structure.

Upon decommissioning, the dried waste will be capped with a minimum 36 inches of cover material. The cover will consist of, from top to bottom, 18 inches of loosely compacted silt, 6 inches of limestone waste rock to be used as a capillary barrier, and at least 1 ft of low permeability material. The entire area will then be reseeded. The reclaimed impoundments will be provided with an undulating surface to alleviate the potential for sheet runoff and erosion.

6.3.2.2 Groundwater

Groundwater near the site occurs in a confined limestone aquifer at a depth of 280 to 360 ft from the surface. The results of a hydrogeologic investigation demonstrated that the aquifer is isolated from the surface by a hard, dense limestone or shale.

The quality of the groundwater is poor, with a TDS level in excess of 3,000 mg/l, unsuitable for potable use without treatment. As explained in Section 5.0, the waste disposal is designed as a closed system. The groundwater will be protected from potential contamination by confining the project's waste in lined impoundments. The impoundments will be lined with an HDPE double liner and leak detection system. The highly calcareous nature of the site's soil will provide a further backup to the liner. The high pH soils will retard contaminant migration by buffering any leachate that might escape the sealed impoundment. Because of the net evaporation rate in the area, the waste will dewater rapidly and no seepage is anticipated upon closure.

6.4 Reclamation

The reclamation will consist of stabilizing the impoundment facility and constructing a protective cover over the facility. The cover will provide a barrier for downward migration of precipitation and a seed bed and root zone for establishment of native vegetation.

The cover will consist of three zones of material. The top zone will be loosely compacted silt from the stockpile area. This zone will provide a growth medium for the root zone and seed bed for revegetation (described in Appendix C). The minimum thickness of this zone will be 18 inches. The next zone will be a capillary barrier consisting of +3-inch limestone rock. This zone will have a minimum thickness of 6 inches and will form a barrier for the upward migration of liquids by capillary action into the top zone. The third zone will consist of a compacted low-permeability cap above the wastes. The minimum thickness of this zone will be 1 ft.

The surface of the reclaimed impoundments will be graded at an average slope of 0.5 percent to drain towards the intersection of the reclaimed surface with the natural ground surface. An undulating surface will be produced to alleviate the potential for sheet runoff and erosion from the impoundment. A stabilized, riprapped channel from the discharge point to the natural drainage on the east side of the impoundments will be constructed.

The diversion ditches will be maintained in working condition. The runoff collection dam will be returned to its pre-project use.

6.5 Monitoring

During construction and operation of the facility, a monitoring program will be carried out to check its performance.

Exploratory wells have been installed on site, and can be used as monitoring wells (well W-2 as shown on Figures 6 and A-1 and well W-3, Figure A-1). The resulting record of groundwater levels and quality can be used to identify any changes in the groundwater regime during operation and whether these changes are caused by the facility.

Water samples from the runoff collection dam will be taken periodically for analysis. These analyses will identify any changes in the surface water quality of the site area and whether these changes are caused by the facility.

During the operation of the impoundment, a record of the quantity of waste deposited and the capacity utilized within the impoundment will be kept. From these observations, a calculation of in-situ densities and equivalent evaporation from the impoundment can be performed for use in predicting facility life and to verify design assumptions.

Pond Leak detection systems will be monitored on a regular basis through a riser pipe installed in each leak detection sump. If required, each riser pipe is capable of receiving a pump to dewater the sump. If needed, an automated pumping system can be installed to maintain solution leakage volumes to less than the volume of the sumps. In this manner, hydraulic head on the lower liner will be minimized at all times.

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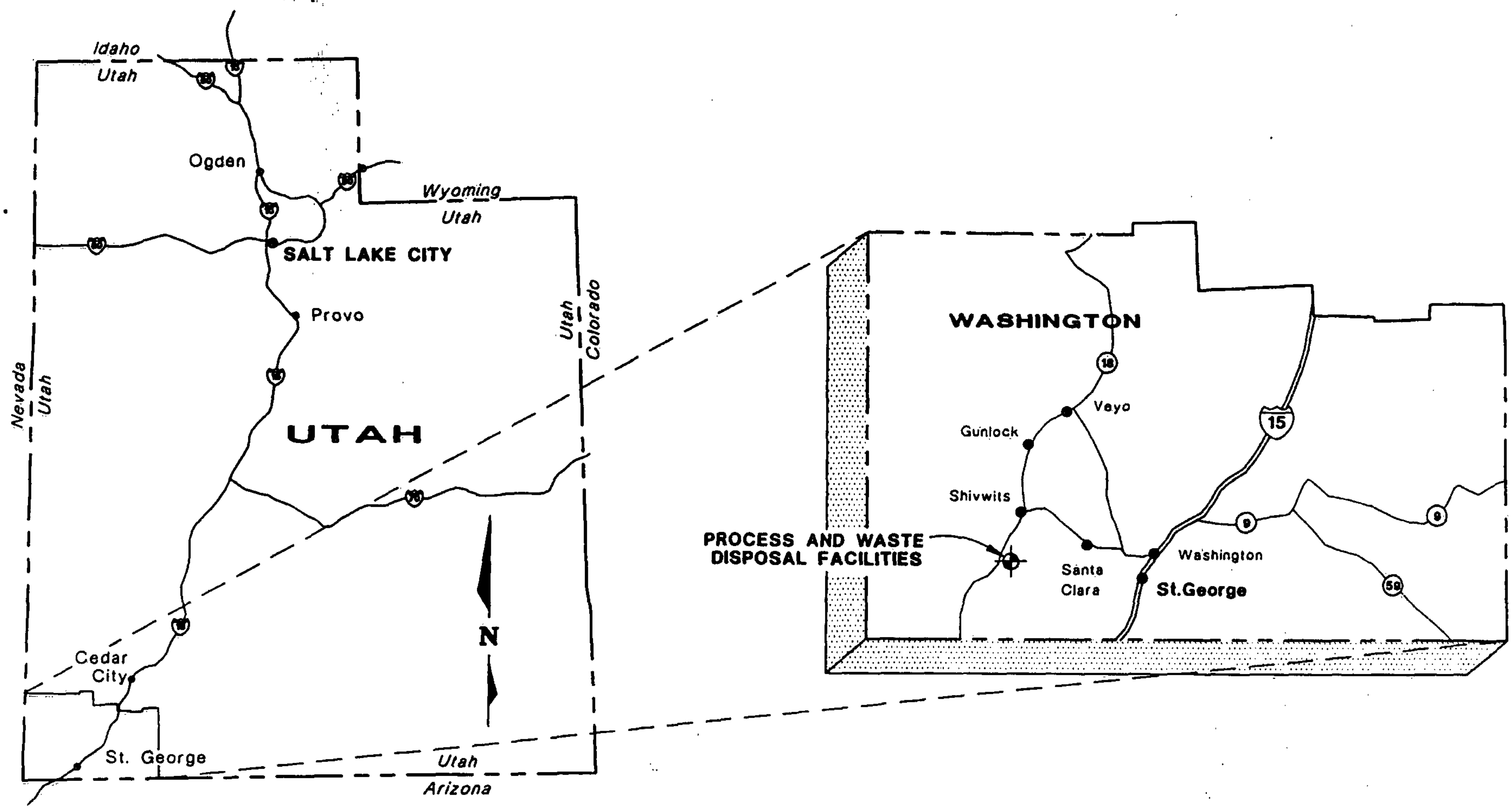
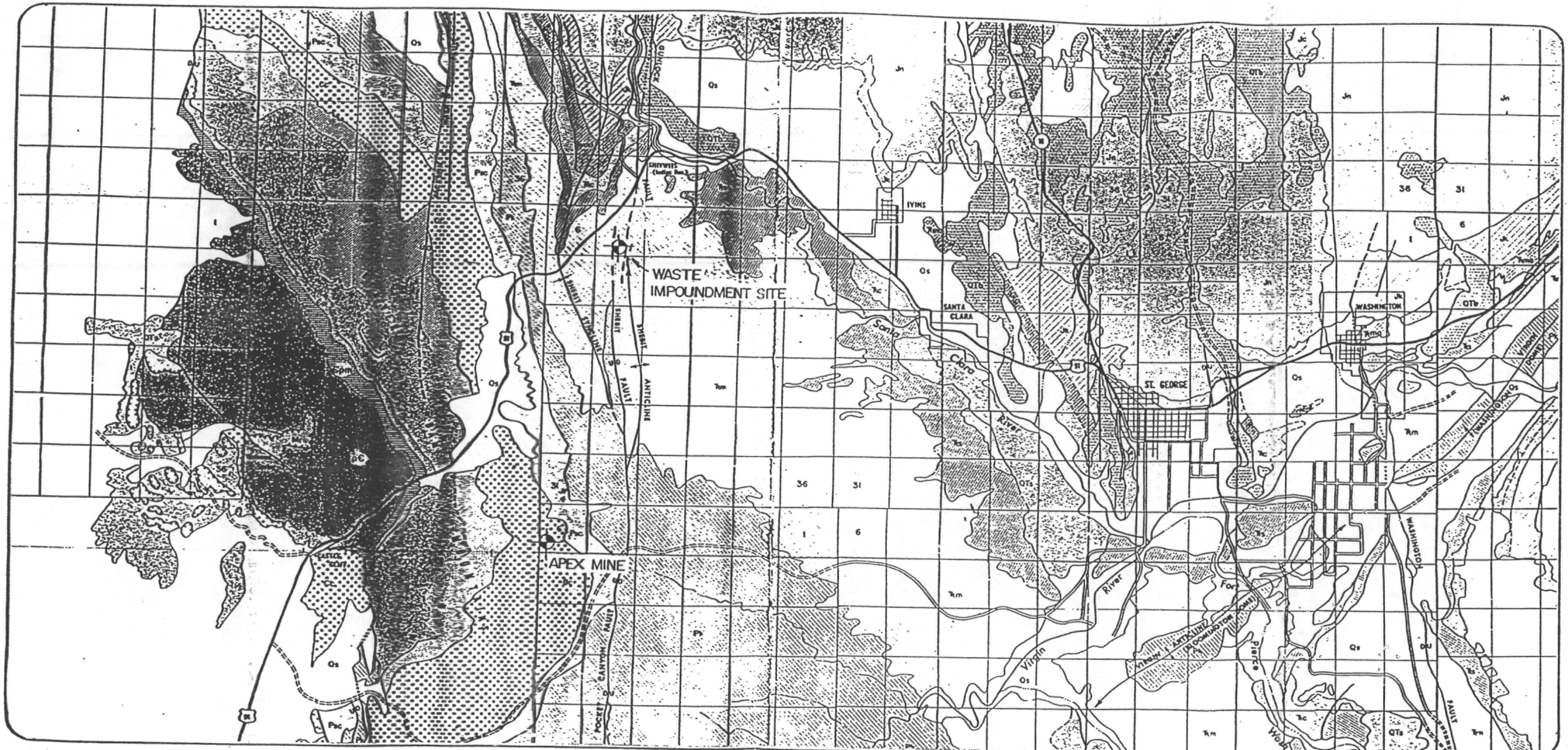


PROJECT NO.	PREPARED BY:	FIGURE 1
22201		
DATE		APEX PROJECT
4/90		HECLA MINING COMPANY
REVISION	STEFFEN ROBERTSON & KIRSTEN (U.S.)	SITE LOCATION MAP
0	Consulting Engineers & Scientists	

PROJECT NO.	PREPARED BY:	FIGURE 2
22201		
DATE		PROCESSING FACILITY LOCATION MAP
3/90		
REVISION	STEFFEN ROBERTSON & KIRSTEN (U.S.)	
0	Consulting Engineers & Scientists	



QUATERNARY

- Qs — Silt, sand, gravel
- QTb — Basalt

JURASSIC

- Jn — Navajo sandstone
- Jk — Kayenta formation

TRIASSIC

- Ŧmo — Moenave formation
- Ŧc — Chinle formation
- Ŧs — Shinarump conglomerate
- Ŧm — Moenkopi formation

PERMIAN

- Pk — Kaibab limestone
- Psc — Supai-Coconino sandstone

MISSISSIPPIAN

- Cc — Callville limestone
- Mr — Redwall limestone

DEVONIAN–ORDOVICIAN

- COD — Limestone

CAMBRIAN

- Cpm — Prospect Mountain quartzite

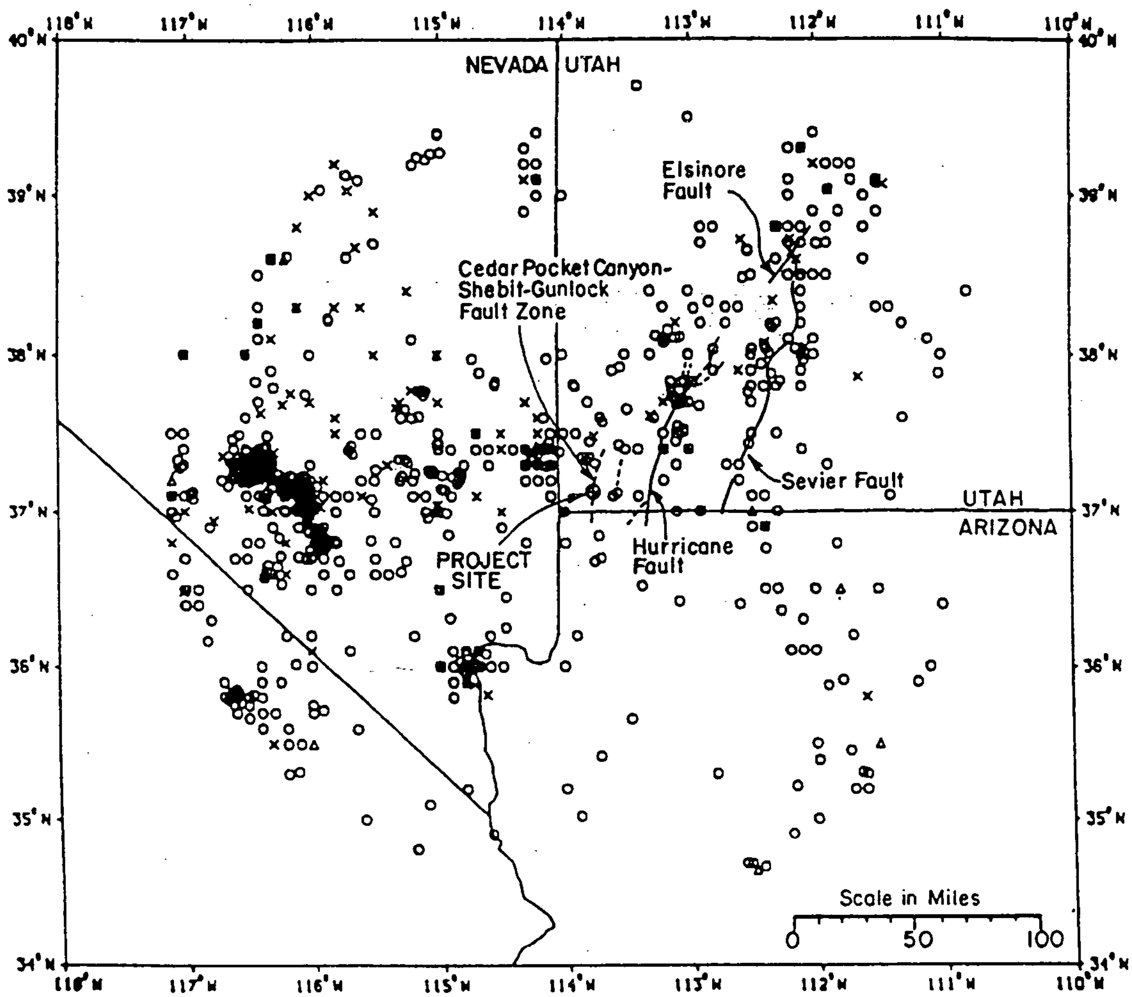
PRECAMBRIAN

- Gneiss, schist, granitic rocks.

SCALE IN MILES

0 1 2 3

PROJECT NO. 22201	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	**FIGURE 3**
FUNCTION NO.		GENERAL GEOLOGY OF SITE AREA. (Adapted from Cook, 1960)
REVISION NO.		



SOURCE OF DATA

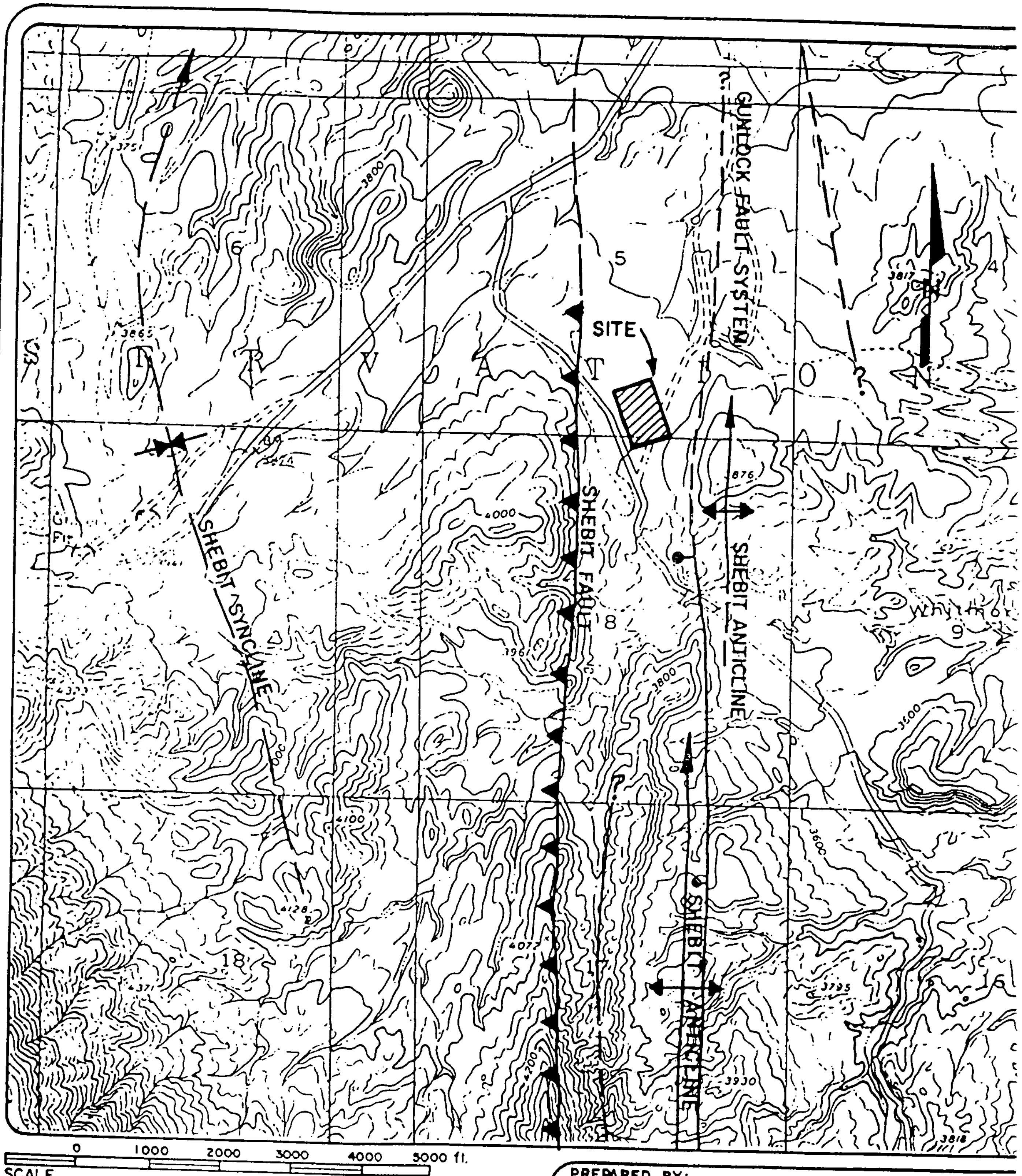
1. EARTHQUAKES : 300 Kilometer radius of site area from National Geophysical Data Center, NOAA, US Dept. of Commerce.

2. FAULTS : From generalized map of young faults in Utah, Arabasz et al., 1979.

EARTHQUAKE MAGNITUDES

o	0.00 M 3.99
×	3.99 M 4.99
△	4.99 M 7.00

PROJECT NO. 22201	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 4
FUNCTION NO.		REGIONAL SUMMARY OF FAULTING & SEISMICITY
REVISION NO.		



EXPLANATION

NORMAL FAULT, DASHED WHERE INFERRED

REVERSE FAULT, DASHED WHERE INFERRED

ANTICLINAL AXIS, DASHED WHERE INFERRED

SYNCLINAL AXIS, DASHED WHERE INFERRED

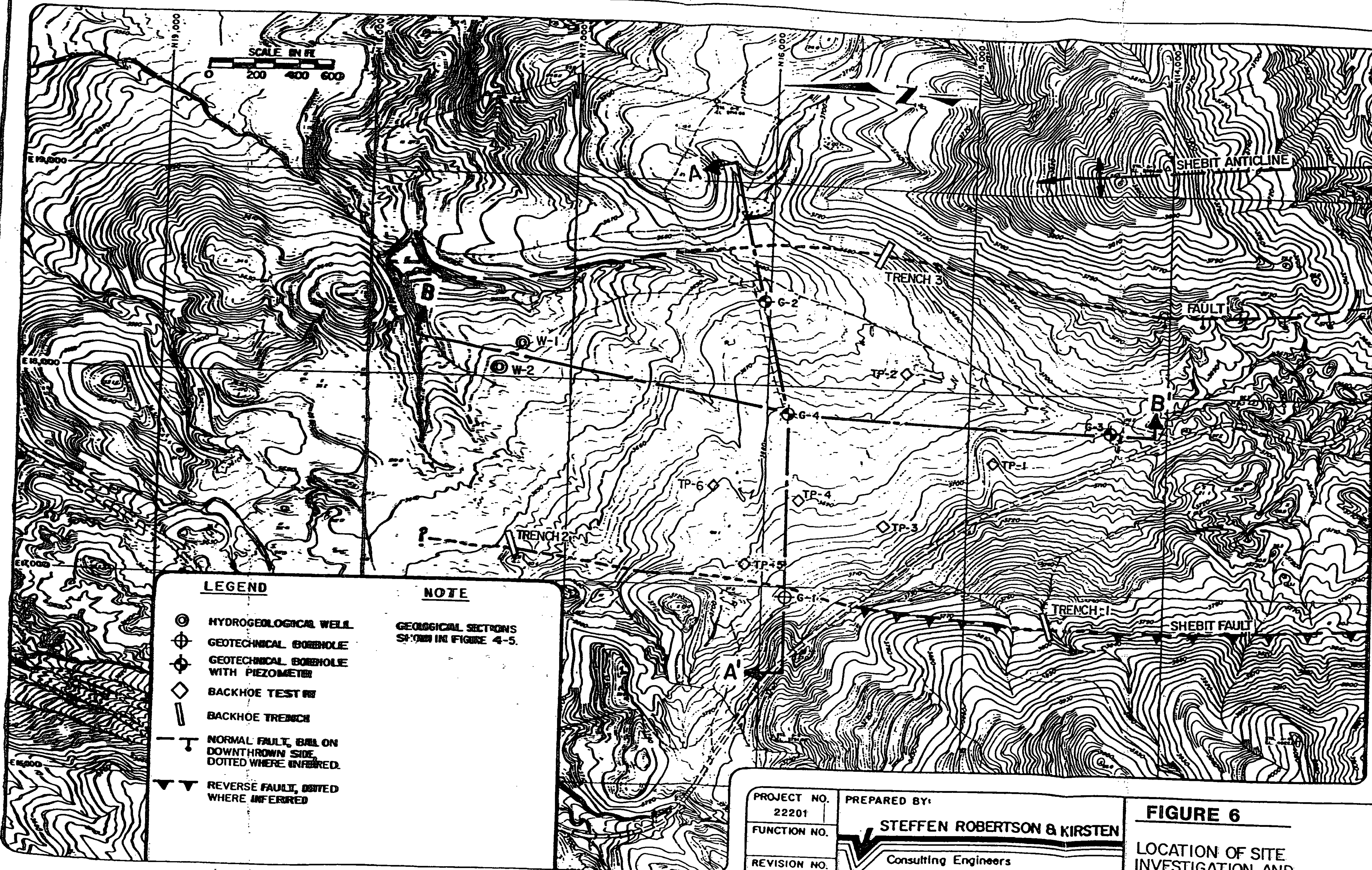
PREPARED BY:

STEFFEN ROBERTSON & KIRSTEN

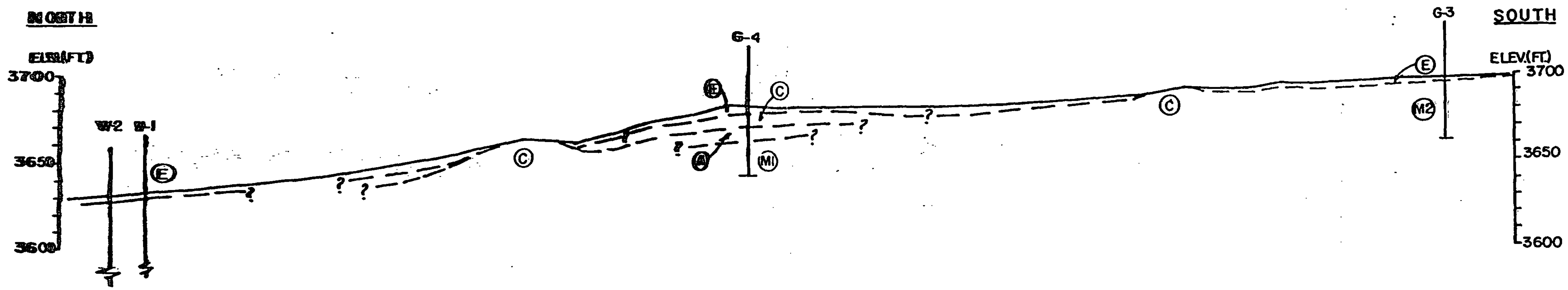
Consulting Engineers

FIGURE 5

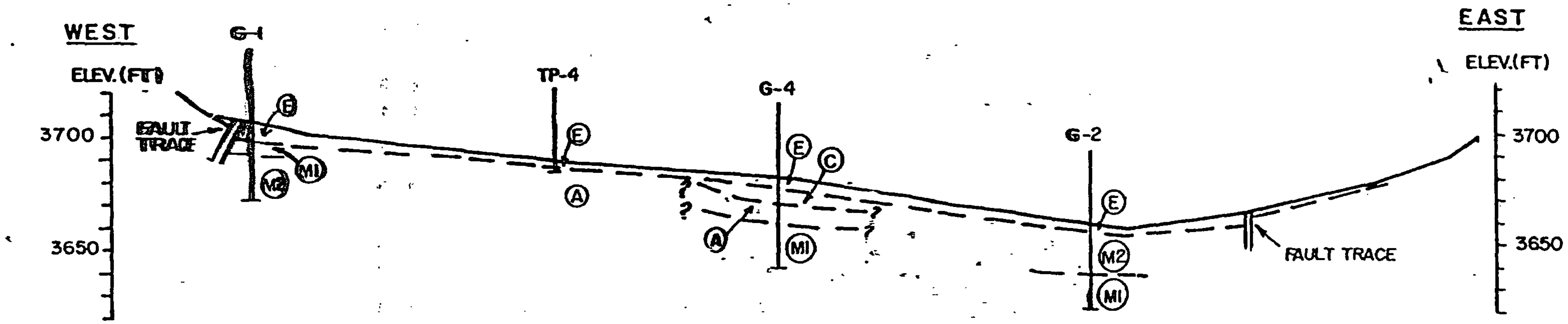
REGIONAL TECTONIC STRUCTURES IN THE SITE VICINITY.
(FROM APPENDIX A.3)



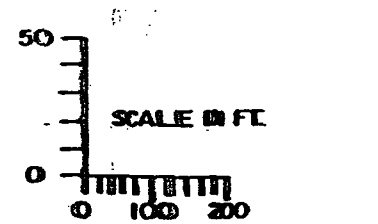
PROJECT NO. 22201	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 6
FUNCTION NO.		LOCATION OF SITE INVESTIGATION AND GEOLOGICAL SECTIONS.
REVISION NO.		



SECTION B'-B'
(LOOKING EAST)



SECTION A-A'
(LOOKING NORTH)



LEGEND

GENERAL SOIL AND ROCK GROUPS

- (E) Slightly gravelly SILT, reddish brown, aeolian-colluvial deposit
- (C) silty, sandy GRAVEL, reddish brown, with zones of caliche, colluvial deposit
- (A) slightly silty, sandy GRAVEL, light brown, alluvial deposit
- (M1) Moenkopi Fm. sedimentary rock, predominantly siltstone, reddish brown
- (M2) Moenkopi Fm. sedimentary rock, predominantly sandstone, yellowish brown to brown
- (M3) Moenkopi Fm. sedimentary rock, predominantly limestone, light brown to gray

EXPLANATION OF SYMBOLS

BOREHOLE/TEST PIT

INFERRED CONTACT BETWEEN GENERAL SOIL GROUPS

PROJECT NO. 22201	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 7
FUNCTION NO.		GENERAL GEOLOGICAL SECTIONS THROUGH SITE
REVISION NO.		

SAMPLE CLASSIFICATION SUMMARY

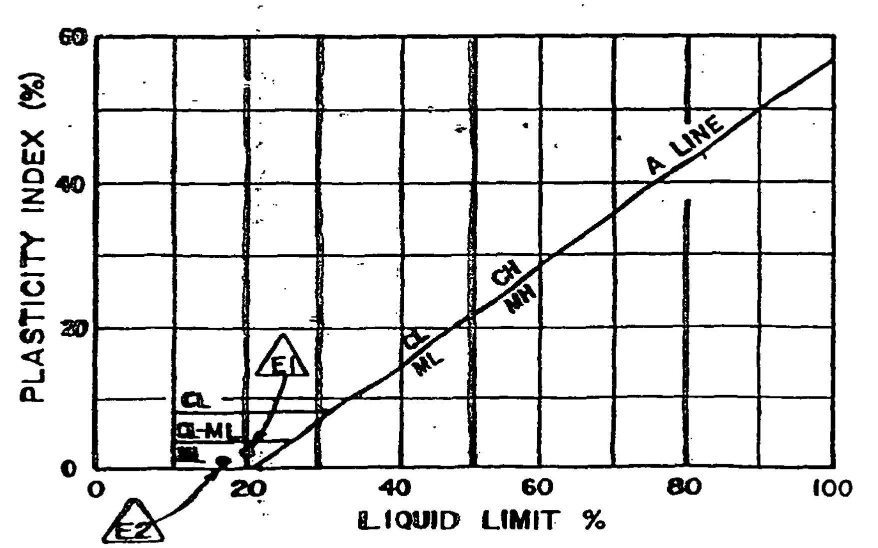
Borehole/Test Pit[a]	Sample	Depth (ft)	Description	Origin	Soil Group[b]	USCS[c]	Specific Gravity	Passing No. 200 Sieve (%)	Symbol
TP-1	1	0-1.5	Silty, sandy GRAVEL	Colluvium	C	GM	—	24	C1
TP-2	1	0-3.0	Sandy SILT	Aeolium	E	ML	—	--	E1
	2	3.0-7.0	Silty, very sandy GRAVEL	Colluvium	C	GM	—	21	C2
TP-6	1	0-2.0	Slightly gravelly, sandy SILT	Aeolium	E	ML	2.66	58	E2
G-2	3	23.0-24.5	Sandy SILT	Bedrock	M	ML	2.72	69	M1
G-3	4	23.0-24.5	SILT	Bedrock	M	ML	—	95	M2
G-4	5	23.0-24.5	Slightly silty, sandy GRAVEL	Alluvium	A	GP	—	9	A1
	7	33.0-34.5	Sandy SILT	Bedrock	M	ML	—	75	M3

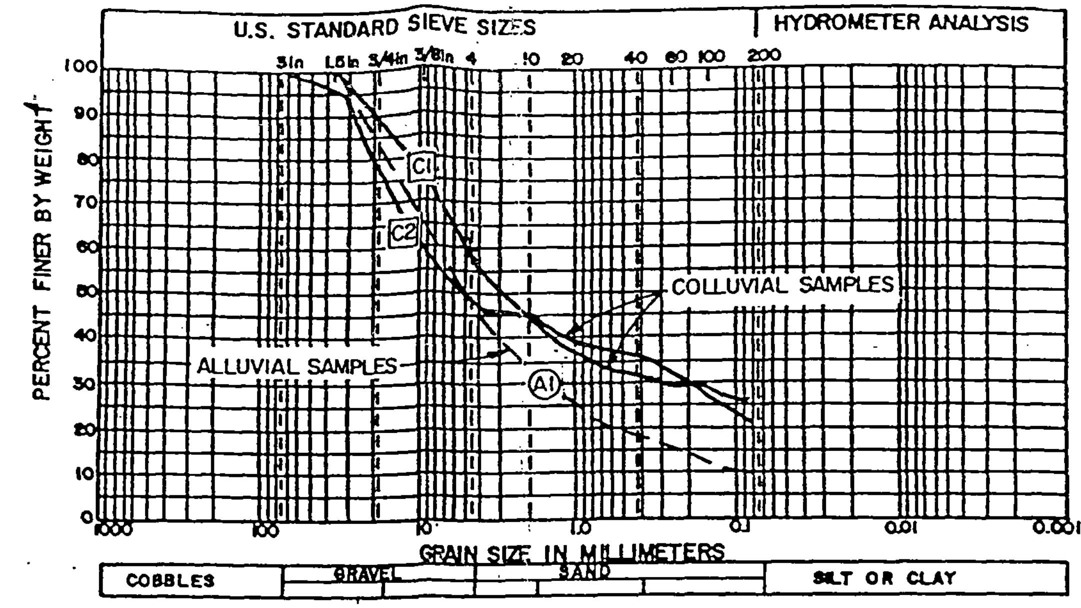
[a] See Figure 4-4 for locations

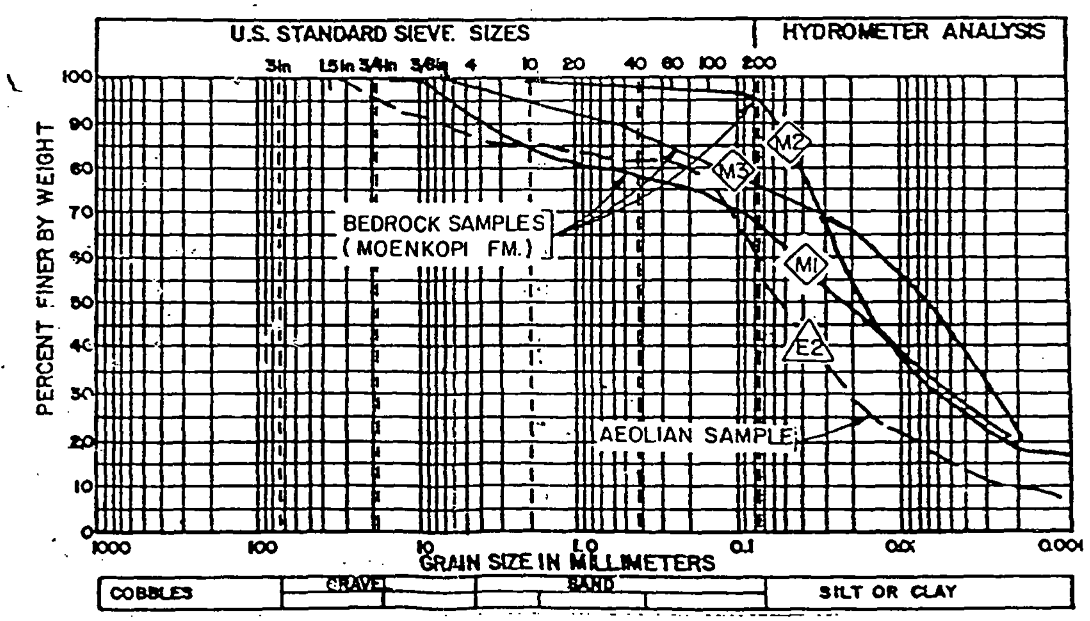
[b] Described in Section 4.4.2

[c] Unified Soil Classification System

ATTERBERG LIMIT SUMMARY







GRAIN SIZE DISTRIBUTIONS

PROJECT NO. 22201	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 8
FUNCTION NO.		GEOTECHNICAL TESTING SUMMARY
REVISION NO.		

ROUTING AND TRANSMITTAL SLIP

Date 3/17/00

TO: (Name, office symbol, room number, building, Agency/ Post)	Initials	Date
1. Linda Jacobson 8ENF-T		
2.		
3.		
4.		
5.		

	Action		File		Note and Return
	Approval		For Clearance		Per Conversation
	As Requested		For Correction		Prepare Reply
	Circulate		For Your Information		See Me
	Comment		Investigate		Signature
	Coordination		Justify		

REMARKS

Compliance & Env. Justice

MAR 20 2000

Received
Office of Enforcement

DO NOT use this form as a RECORD of approvals, concurrences, disposals, clearances, and similar actions

FROM: (Name, org. symbol, Agency/ Post)	Room No. — Bldg.
Lauren Buehler 8ENF-L	Phone No. 7054

5041-103

OPTIONAL FORM 41 (Rev. 1-94)
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